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SVIC NOTES

FLOW INDUCED VIBRATIONS

One of the highlights of the 1984 ASME Winter Annual Meeting was the multiple sessions on flow-induced vibrations. These sessions were organized as a cooperative effort by several divisions of the ASME; and, they indicate a continuing and widespread concern over the destructive potential of this type of vibration. But more important, these sessions reflect the almost worldwide research that has been carried out during the past years to obtain a better understanding of the behavior of objects subjected to this form of excitation.

In general, the concept of flow-induced vibrations has been known for many years, and many mechanisms are available for exciting these vibrations; vortex shedding and galloping are two well known examples.

There are many reasons why flow-induced vibration problems might occur -- and one of these is the requirement for higher performance. The tube vibration problem in some of the early designs of shell and tube heat exchangers for nuclear power plants is a good example. In this instance, the higher performance requirement was in the form of a higher heat transfer rate, and this led to higher velocity fluid flows over the tubes which often produced destructive vibrations. Papers on flow-induced vibration problems in heat exchangers during the early period reflected the research efforts that were undertaken to obtain a better understanding of the nature of this type of excitation. But, an additional goal of many of these efforts was to develop techniques for designing heat exchangers to prevent vibration-induced tube damage. This goal has been met to a large extent since many papers in the two sessions on flow-induced vibrations in heat exchangers at this meeting provided guidelines, or algorithms, for designing heat exchangers to avoid some of the flow-induced vibrations problems.

The wind-induced vibration of structures has been extensively studied. Typical structures that might be excited by wind forces include suspension bridges, launch vehicles, spacecraft assemblies, and smokestacks. Recently, problems with excessive wind-induced vibrations of some modern high-rise buildings have been reported in the literature. Some modern buildings are prone to wind-induced vibration because they are more flexible. In addition, the building framework is often welded, instead of riveted, which means less structural damping is available to control the building vibrations. While I am not aware of any structural failures of buildings caused by wind-induced vibrations, they are, nevertheless, potentially destructive to plaster walls, mechanical equipment or piping systems. Such vibrations are also annoying to occupants of the upper stories of such buildings. In some cases, these vibrations have been controlled by designing a stiffer structure. In other cases, the building vibrations have been controlled by adding passive damping treatments, or by using passive or active vibration absorbers. But, in view of the advances in incorporating added damping treatments as a part of the overall structural design process, this method for controlling building vibrations by design should be explored further.

To conclude, I believe substantial progress has been made in understanding the nature of, and controlling, flow-induced vibrations. Because of this progress, I believe we are in a better position to recognize potential situations where several types of flow-induced vibrations problems might arise.

R.H.V.

EDITORS RATTLE SPACE

THE APPLICATION OF MICROCOMPUTERS IN VIBRATION ENGINEERING

The microcomputer explosion has vastly raised the potential capabilities -- in both computation and measurement -- for those involved in vibration engineering. In fact, microcomputers should stimulate a union of measurement and computation that will provide more solid design, development, and analysis tools. Many companies have purchased microcomputers for their engineers, thereby giving them the hardware necessary to do a job. But, realizing the potential of this technology is not without problems.

As I see it lack of both training and software restrains us from taking full advantage of microcomputer capabilities. The most basic requirement is training on the use and capabilities of the microcomputer. Without such training the equipment is of no use. Many engineers educated prior to the computer age are reluctant even to try to use one. Even those engineers who have programmed on main frame computers have to deal with new hardware and operating systems. In my experience the operating manuals that accompany microcomputers are not the best. Perhaps a good investment for today's experienced engineer would be a few basic courses on the microcomputer and its capabilities -- provided such courses exist.

The second area that restricts the use of microcomputer hardware is software. Much of the software available for microcomputers is special purpose. A recent issue of **Mechanical Engineering** magazine contained an article titled "Finite Element Analysis Packages for Personal Computers."* Such a title is indicative of the software coming on the market. However, this new software capability has not yet been attempted in many areas of vibration engineering.

For the vibration engineer the simple part of applying the microcomputer to vibration engineering has passed. It's time for the tedious tasks of training and application to begin. The results of these processes will determine how effectively and widely used the microcomputer will be in engineering.

R.L.E.

*Falk, Howard and Beardsley, Charles W., "Finite Element Analysis Packages for Personal Computers," **Mechanical Engineering**, pp 54-71 (Jan 1985).

THE EFFECTS OF SEISMIC WAVES

Sasadhar De*

Abstract. This review article deals with the effects of seismic waves on ground motion and structures, mechanisms and prediction of earthquakes, abnormal animal behavior before earthquakes, and disturbances in the ionosphere. Some recent problems in seismology are described.

GROUND MOTION AND STRUCTURES

The motion of the ground in the near field of a fluid-driven tensile crack [1] and motion at four azimuths with constant epicentral range due to a buried circular strike-slip fault [2] in a half-space have been studied. Ground motion from a propagating stress relaxation [3], strong-motion duration and rms acceleration of earthquake ground motion [4], and motion velocities and displacements [5] have been discussed. Earthquake ground motion characteristics on and around cliffs have been investigated [6]. A ray method has been used [7] to calculate the near-field ground acceleration excited by sliding on a fault plane. A model of nonhomogeneous faulting has been considered [8] in a study of strong ground motion for some tremors and earthquakes at close hypocentral distances. Interrelations among various magnitude scales have been examined to develop an earthquake ground motion model [9]. A numerical approach to motion analysis has been proposed [10]; motion recorded in a highly seismic region has been discussed [11].

Expansion of pore fluid due to frictional heating can affect frictional resistance and temperature during an earthquake and is possibly therefore a controlling influence on the physics of the earthquake process [12]. The influence of pore water on dynamic soil-structure interactions [13] and limitations of the amplitudes of transverse and longitudinal vibrations of thin-walled structures with a fluid [14] have been studied.

The seismic response of a structural system depends on its mass, stiffness, and damping characteristics. The eccentricity between the mass and stiffness centers of most buildings affects their dynamic response. These quantities are considered as random variables; the calculated dynamic response should reflect the uncertainties associated with these parameters. The sensitivity of seismic response with respect to changes in these parameters has been discussed [15]; displacement, base shear, base torsional moment, and column moment response of a multistory rigid floor system have been studied. Ground motions; earthquake-resistant designs of buildings and rural housing; and the dynamic behavior of structural materials and components of nuclear power plants, dams, and other hydraulic structures including buried ones have been discussed [16]. Underground structures in general are less severely affected by seismic activity than surface structures at the same geographic location; literature on the nature of underground seismic motion has been reviewed [17].

The structural response of a 40-story building under the excitation of horizontal earthquake ground motion varies greatly with the direction from the building site to the epicenter [18]. A design criterion for multicomponent earthquake input has been proposed [19]. The earthquake response of symmetric elastic structures [20] subjected to SH-wave excitation and to Rayleigh waves has been studied. The responses of 23 single-family residences to motions from surface mining blasts have been analyzed [21] using Fourier power spectral density and transform functions. The lateral-torsional responses of structures subjected to

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the action of both free-field ground inputs and external forces and moments [22] have been studied, as has the stability of an elastic structure situated at the boundary of an elastic half-space under the action of harmonic Rayleigh waves [23].

The earthquake response of reinforced concrete structures having abrupt interruptions in lateral force-resistivity elements in adjacent stories has been studied [24]. Existing earthquake instrumentation programs for buildings have been reviewed and summarized [25]. The dynamic behavior of PWR-RCC fuel assemblies under seismic excitation has been investigated [26]. A method for evaluating the dynamic response of base-isolated nuclear power plants and the performance of aseismic rubber bearings in the vertical direction have been presented [27]. The response of a shear wall on an elastic half-space [28] due to the excitation of plane SH-waves and response of a hemispherical shell in a fluid medium to ground motion [29] have been studied. An evaluation of seismic safety of buildings subjected to earthquake loads has been presented [30]. Design information on the behavior of structures during earthquakes [31, 32] and the inelastic response of coupled walls [33] subjected to earthquake excitations have been considered.

The hydrodynamic and foundation interaction effects on earthquake responses of dams [34] have been studied, as have the responses of concrete gravity dams to the transverse (horizontal) and vertical components of earthquake ground motion [35]. An analysis of hydrodynamic loads on submerged structures has been reviewed [36]. Seismic responses of submerged, underwater oil storage tanks [37] and of liquid storage tanks [38, 42] have been studied. Seismic phenomena relative to buildings, bridges, dams, and other structures have been investigated [43, 44]. The earthquake responses of suspension bridge towers [45], bridges [46], dam-reservoir systems [47, 48], arch dams [49], and nonhomogeneous earth dams [50] have been analyzed.

Seismic responses of chimneys [51] and buried pipes [52] have been discussed. Seismic design considerations and building codes for various types of non-nuclear structures have been analyzed [53]. The behavior of moment connections and beam-column joints in moment-resisting steel frames [54] subjected to severe earthquakes has been discussed. The acceleration profiles at lower elevations of cantilever structures and the responses of relatively rigid structures have been explored [55]. The response of a non-seismically designed 11-story reinforced concrete building subjected to mechanically induced large-amplitude shaking has been correlated with an actual inelastic response measured from full scale tests [56]; the response of the structure subjected to earthquake-induced ground motion was also studied [56].

Seismic research for the development of a high-temperature gas-cooled reactor has been conducted [57, 58]. An analysis for tall buildings implemented by active control systems and excited by earthquake ground motions [59] has been considered. The durations of ground motions relevant to the behavior of structures during earthquakes have been compared [60]. Guidelines for the seismic design of highway bridges have been published [61]. A technique [62] for estimating earthquake response of a mechanical appendage system has been studied. The statistical properties of the response of a linear elastic tall building [63] and hysteretic columns [64] under earthquake excitations have been considered by an analytical method. The development of linearization methods suitable for the earthquake analysis and design of yielding structures has been discussed [65]. The seismic behavior of a three-story steel structure subjected to arbitrary forcing functions has been considered [66].

A computer program has been developed to simulate the motions of bodies subjected to horizontal and vertical ground motions [67]. Numerical integration of the equations of motion has been used [68] to evaluate the adequacy of modal solutions applied to the analysis and design of large offshore structures under wave and earthquake loadings. The use of modal analysis to obtain quantitative information on the seismic behavior of complex structures has

been discussed [69]. The application of an analytical model (Q-model) for calculating the nonlinear seismic response history of irregular planar structures has been demonstrated [70]. The ultimate limit state design of steel buildings against an earthquake on the basis of the energy concept [71] has been considered, as has the seismic analysis of a structure subjected to translational and rotational base excitation [72]. Nonlinear analyses have been conducted to assess the survivability of concrete gravity platforms during earthquakes [73]. The finite element technique has been used to compute the nonlinear behavior of reinforced concrete planar structures during earthquakes [74]. The inelastic seismic analysis of large panel structures has been mathematically considered [75]. Some models to determine the dynamic response of simple underground structures in the state of plane strain have been developed [76]. The influence of the constitutive model chosen to represent the earth on the response to seismic waves of an embedded rigid structure [77] has been studied, as have the elastic and inelastic responses of reinforced concrete frames subjected to earthquake motion [78]. The stochastic earthquake response of structures on sliding foundations [79] and the minimum intensities of excitation that cause structural collapse [80] have been discussed.

The seismic response of long-period structures at an intermediate distance from a fault has been considered [81]. A methodology for reliability assessment of structural systems subjected to seismic risk has been presented [82]. A survey of existing analytical and experimental work regarding the seismic response of R/C wall and coupled wall-frame systems is available [83]; analytical studies of the seismic responses of the prototype buildings were summarized.

MECHANISM AND PREDICTION OF EARTHQUAKES

Studies of the upper mantle and the regional variation of its seismic structure are necessary to understand the mechanism of earthquakes and their source parameters in the light of earthquake prediction, movement of lithospheric plates, and tectonic processes.

Stress and strain inside the Earth. The Earth is considered a sphere of radius with a rigid core of radius b (<a) at the center. It is supposed to be at rest under the mutual gravitation of its own parts. Let $u_r = U(r)$ be the symmetrical radial displacement and u = u = 0. The non-vanishing strain and stress components are respectively given by

$$(1)\quad e_{rr} = \partial U/\partial r,\ e_{\theta\theta} = U/r,\ e_{\phi\phi} = U/r$$

and $$\widehat{rr} = (\lambda+2\mu)\ \partial U/\partial r + 2\lambda U/r$$

$$(2)\quad \widehat{\theta\theta} = \widehat{\phi\phi} = \lambda\ \partial U/\partial r + 2(\lambda+\mu)U/r,$$

λ, μ are Lamé constants.

The only non-vanishing body-stress equation of equilibrium is

$$(3)\quad (\lambda+2\mu)\ \partial/\partial r\ (\partial U/\partial r + 2\ U/r) + \rho F_r = 0,$$

ρ = density of the Earth and F_r = radial body force ($\equiv$ - gr/a, g is the acceleration due to gravity). The conditions are

$$(4)\quad \widehat{rr} = 0 \text{ at } r = a$$

$$\text{and}\quad U = 0 \text{ at } r = b$$

From equation (3) after integration

$$(5)\quad U = g\rho/10a(\lambda+2\mu) + C_1 r/3 + C_2/r^2,$$

C_1 and C_2 are any constants.

Equation (4) is used to eliminate C_1 and C_2; thus the stress $\widehat{rr}$ and the strain e_{rr} can be obtained. If $e_{rr} < 0$, contraction occurs; if $e_{rr} > 0$, extension occurs. Stress and strain are functions of g aswell as the elastic moduli.

Earthquakes basically result from strain accumulations in rock that lead to catastrophic fractures; the fractures radiate the accumulated strain energy as waves [84]. The fault movement associated with a big earthquake is perhaps the most spectacular evidence for living tectonics in the Earth. (A fault is a slip surface in the Earth, across which discontinuous land movement, or offset, takes place.)

The focal mechanisms of some earthquakes have been discussed [85-99]. The three-point [100] and four-point [101] moment functions of the spatial distribution of shallow earthquakes have been considered. A method to study focal regions of earthquakes based on observations of structures resulting from the destruction of rock exposures, called seismoglyphs, has been discussed [102]. Fault movements and stress accumulation before the 1976 Tangshan earthquake have been analyzed [103]. The seismicity in an area has been studied using a telemeter observation system [104]. The stress field of the Japanese islands has been studied by analyzing geographical height data [105]. The character of the recent tectonic movement of the BaBao Shan Fault has been investigated [106].

A model of the expansion of a crack in an elastic medium has been considered [107]; friction depended on the slip rate and the modulus of cohesion depended on the speed of expansion of the crack. A possible qualitative explanation of several forms of earthquake clustering, including clustering that precedes strong earthquakes, was given.

Regional variation of the crust and uppermost mantle structure in Japan has been estimated [108] from an analysis of P_n arrivals. The focal mechanisms of some earthquakes in the area of the Nurek Reservoir have been attributed to additional stresses from the water load and the strain caused by elastic warping of the bottom of the reservoir [109]. The precursory gaps before two moderate earthquakes inside the continental plate of China have been examined [110]. The source parameters of acoustic emission generated by crack generation in a granite sample have been determined [111].

Earthquakes are usually assumed to occur when the gradual stress buildup in a region eventually exceeds some initial local strength. A number of mechanisms, which must play a significant role in stress redistribution in active earthquake regions, have been discussed [112]. The excitation of seismic waves by an indigenous seismic source when the source volume is intersected by a structural discontinuity [113] has been theoretically considered. The seismogeological background of the Songpan-Pingwu earthquakes, their seismicity, the characteristics of the tectonic stress field, and the conditions of the seismogenic structures in the region under investigation have been discussed [114]. The excitation of the earthquake displacement field on polar motion of the Earth [115] has been studied. The sequences of premonitory stages by elastic and plastic responses have been described [116]. Multipolar analysis has been used to study the Vrancea earthquake [117]. The relations between the ratio of seismic compressional and shear wave velocities (V_p/V_s) and sedimentary rock lithology have been considered [118].

Seismicity related to a given fault area is governed by the distribution of the difference between shear stress and frictional stress over the fault surface [119]. The seismicity of the region of the Chu depression basin and its mountainous framework has been examined [120]; focal mechanisms of earthquakes were investigated. The relationships between the distribution of earthquakes and changes in the stress field in Yunnan have been discussed [121]. Focal depths below the seafloor have been determined [122] for some of the larger shocks associated with the Great Sumba earthquake. A correlation between recent shallow and mantle earthquakes in the Izu region has been discussed [123]. The tectonomagnetic event accompanying the Higashi-Izu earthquake has been described [124]. An active earthquake swarm has been studied [125]. A temporal seismic

network and wireless telemetry have been used to precisely determine the distribution of hypocenter locations [126].

If radon changes associated with earthquakes are caused by changes in strain within the Earth, reports of radon signals that are measured at considerable distances from the hypocenters of earthquakes can be understood. A dislocation model for estimating distances has been discussed [127]; the strain from a dislocation loop varies at large distances x as x^{-3}. Strains increase with the magnitude of the earthquake represented. A track etch method has been used to analyze changes in radon concentration in soil gas on lines across some faults for earthquake prediction [128]. Hydrogen concentration in soil gas has been measured around a fault; the production of hydrogen by fault movements has been reported [129]. The seismic activity of the western coast of India has been studied [130] by measuring the radon content of the gas emanating from several hot water springs. The dilatational impulsive forces from a blast have been reported to be the principal causes of variation in radon and other hydrochemical components of ground water [131]. The influence of the change of topography of Earth relief during earthquakes has been considered [132].

A preseismic fault slip process is one possible mechanism to explain observations of relatively long-term anomalous surface deformations preceding large crustal earthquakes [133]. A possible correlation between intermediate earthquake activity in the Vrancea region and the state of stress around a fault in the crust [134] has been studied. The dynamics of a strike-slip vertical fault in a half-space has been considered [135]. The spatio-temporal variation of the seismic gaps associated with some major earthquakes [136] has been studied. The concepts of fracture mechanics have been used to discuss an earthquake mechanism that includes the phenomenon of subcritical crack growth [137]. An earthquake swarm sequence has been studied on the basis of waveform analysis [138]; the sequence of earthquake activity has been described [139]. A tripartite microseism network has been installed to study seismic activity [140]. Surface faults associated with the Rikuu earthquake [141] and the seismic behavior of a large rockfill dam [142] have been considered. Generation of seismic waves by tsunami waves has been investigated [143]. Fault plane solutions for some main shocks have been studied [144]. The field of the longitudinal waves radiated by a shear fault has been discussed [145].

Earthquake source parameters, velocity ratio, amplitude ratio of P and S waves, and focal mechanism solutions have been considered [146]. Teleseismic long-period body and surface waves radiated by an earthquake have been studied to determine source characteristics [147]. The intraplate seismicity of the south-central Pacific Ocean has been considered [148]. The concept of plate tectonics and dynamic features such as volcanism and earthquakes have been discussed [149]. The focal mechanism of an earthquake provides evidence of contemporary thrust faulting in southeast Australia [150]. The earthquake is modeled as a propagating fault buried in a medium consisting of a two-layer crust overlying the mantle [151]. A significant change in the time rate of earthquake clustering around 60 to 70 km depth [152] has been studied. A statistical analysis of stress drops measured in different earthquake sequences has been presented [153].

Earthquakes represent repeated stress release at the same asperity, or stress concentration, along a fault surface; identifications of such asperities can be useful in understanding the sequence of events leading to the initiation of a large earthquake [154]. Strain and mechanical conditions as well as horizontal crustal movement around the Yishu Rift Valley in Central and South Shandong have been analyzed [155]; possible future earthquake occurrences were determined. The theory of membrane tectonics has been extended to the case of a viscoelastic lithosphere [156]; a secondary role in the generation of intraplate features and earthquakes was also discussed. Seismic gaps and recurrence periods of large earthquakes have been examined [157]. The earthquakes associated with the Rocky Mountain Arsenal disposal well have been studied [158].

The statistical distribution of stress relaxation associated with earthquakes and the mechanism of accumulation of stress [159] have been studied. The nature, origins, and effects of tsunami have been discussed [160]. Geological conditions and geophysical fields of earthquakes have been investigated [161]. Anomalous crustal deformation has been shown as an early indication of earthquake development [162]. The upthrust deformation caused by the volcanic activity accompanying numerous earthquakes has been studied [163]. Correlation between the time an earthquake originates and tidal potential has been discussed [164].

An earthquake caused by a thrust fault has been studied [165]. Some earthquake models based on the elastic theory of dislocations have been presented [166]. Basement faulting and focal depths of a large earthquake have been described [167]. Variations of tectonic stress before the Tangshan earthquake [168] have been considered. The stress, deformation, and tilt fields of earthquake sources have been investigated [169]; the seismotectonic condition for the occurrence of strong earthquakes and the credibility and generality of the elastic rebound theory were also studied. The source parameters of an earthquake have been determined on the basis of close-in long-period seismograms [170]; source mechanisms of some events have been discussed [171]. Geologic and tectonic conditions leading to the Ogoron earthquake [172] have been studied, as have the nature of the course of seismicity and the time relationship of crustal earthquakes of different strengths [173]. The faulting mechanism of the Kanto earthquake [174] has been described, as have features connected with the formation of the oscillation field in the zone closest to the focus [175]. The concentrated accumulation of tectonic regional stress has been considered [176] in a study of aftershock.

The rupture mechanism of earthquakes has been studied [177]. A method for defining an earthquake nest has been proposed [178]; an application of the method to microearthquakes was shown. A non-tectonic earthquake, or cryoseism, caused by freezing action in ice, ice-soil, and ice-rock materials has been studied [179]. The spatial characteristics of a seismic wave field in rock permafrost soils have been shown [180]. The earthquakes caused by horizontal bending of the Philippine Sea plate have been studied [181]. The seismicity of volcanic and tectonic earthquakes in and around volcanoes has been considered [182].

A catalog of seismic events with assigned magnitudes for the Middle East has been discussed [183]. Focal mechanisms, intensities, and epicenters of recent French earthquakes have been considered in a seismotectonic map of France [184]. Seismicity mapping in terms of released seismic wave energy [185-187] and the magnitude of an earthquake related to a fault [188] have been studied.

A model of correlation between seismicity and a specified component of tidal stress has been proposed [189]. The finite difference method has been used to study dynamic shear crack [190]. A viscoelastic finite element method has been used to formulate an elastic rebound model for normal fault earthquake cycles [191]. A study of spatial correlation shows that large historical earthquakes in eastern North America are possibly associated with deep-seated faults [192]. Some models for stress relaxation in the Earth and related post-seismic deformations have been discussed [193]. Shallow strike slip earthquakes on vertical faults have been modeled as two-dimensional antiplane strain ruptures in a uniformly prestressed homogeneous half-space [194].

Earthquake prediction is important in seismology. Specific predictions are based upon observed anomalies in certain geophysical parameters before an earthquake occurs [195, 196]. These anomalies, considered precursors to an earthquake, alter rather quickly just before an earthquake, thus making the prediction possible. Precursors are generally either bay form or peaked form. Bay-form precursors recover to their normal level before an earthquake; peaked-form precursors are at a maximum level at the time of the earthquake and recover to a normal level afterward. Cer-

tain patterns of seismicity [197-203], changes in earthquake focal mechanisms [205-208], instances of variations in earthquake spectra [209, 210], changes of seismic velocities and V_p/V_s ratios [211-214], as well as changes of elastic moduli [215] are some of the commonly considered precursors to an earthquake. The influence of seismic activity on the characteristics of underground and surface waters -- i.e., chemical composition, content of dissolved gases and radioactive elements, level of water in deep wells and boreholes, yield from oil and gas wells, and content and type of isotopes in water and rock -- have been used to predict strong earth movements [216]. Geochemical precursors are reported to be useful in forecasting earthquakes. A review of premonitory variations of geochemical parameters before the occurrence of earthquakes has been considered; some results concerning the reducing capacity of fumarolic gases in the island of Vulcano (Italy) have been reported [217]. Current advances in various aspects of earthquake prediction have been reviewed [218]. The role of space technology in earthquake prediction research has been discussed [219].

A sensitive laser phase-lock strainmeter has been used to study the general motion of a strain wave which is the precursor of a typical earthquake [220]. Observations of increases in groundwater temperature have been used to monitor the crustal strain and movement of groundwater related to earthquake occurrence [221]. Precursor events have been included in a Poisson process of earthquake occurrence; the result is a warning time from precursor event to actual earthquake [222]. The contribution due to slight irregularities of initial stress and sliding frictional stress to rupture motions have been studied [223]. Anomalous mechanoelectric phenomena in water-saturated rocks have been investigated [224]. A change in apparent resistivity was observed before and after the Izu-Hanto-Toho-Oki earthquake [225] and before the 1976 Tangshan earthquake [226, 227]. The resistivity variation of the ground has also been used to study earthquake prediction [228-231]. Precursory seismic velocity and electrical conductivity of stressed and deformed materials have been considered in laboratory experiments [232]. Fluctuations in temperature and their relation to the occurrence of earthquakes have been discussed [233]; earthquakes occur more readily in cold periods and in periods of drought. An observation of the relation between a kind of pressure wave in the atmosphere and local earthquakes has been reported [234]. Changes in the Earth's magnetic field have been related to changes of climate [235].

Seismic data during the past 500 years have been used to show variations in the activity of active seismic regions [236]. A medium-term prediction for the magnitude and epicenter of an impending earthquake is based on the result of an analysis of a variation of the seismic wave velocity ratio of a region of about 2×10^4 km^2 in extent [237]. Large earthquakes ($M \geq 6.75$) in the Mediterranean region have been investigated [238] with the aim of establishing possible regularity patterns in their occurrence and of identifying regions of seismic potential. The concept of failure rate in the theory of reliability has been used to study earthquake prediction [239].

The anomaly of radon content in groundwater has been noted as a precursory phenomenon for earthquakes [240-248]. The radon concentration increases before and during seismic events, then decreases before returning to a normal value [249]. It is possible that the increase in radon content in water after a main shock is related to a strain adjustment in the region of the source of the earthquake and to a cumulative increase of macroscopic fractures of water-bearing rock formations [250]. The emission of gas from the Earth's crust before an Earthquake is a complex process influenced by meteorological and seasonal parameters. Radon emanation has been correlated with instrument vault temperature, barometric pressure, outside temperature, soil temperature, and whether or not surface soil is frozen. Mercury emission correlates with vault temperature, vault relative humidity, outside temperature, barometric pressure, soil temperature and moisture, and the soil freeze-thaw cycle [251]. Earthquakes release gases from deep in the Earth's mantle [252]. The emission of gas from the Earth's crust and

the influence of meteorological and seasonal parameters as well as radon emanation have been studied to predict earthquakes [253]. Coseismic temperature changes in the groundwater of wells have been reported at the time of occurrence of volcanic earthquakes [254]. Unusual phenomena in subsurface fluids (such as groundwater, gases, and petroleum) have been reported several days or hours before strong Chinese earthquakes [255]. The variation of radon content of underground water is related to fracturing of the rock medium [256]. Changes in the helium/-argon ratio of gas bubbles in a mineral spring along a fault zone coincided with fluctuations induced by tides [257]; the observation suggests that deep-seated gases characterized by higher helium/argon ratios are squeezed out by stresses preceding an earthquake. The concentration of ^{222}Rn in air has been measured [258] with a flow-type ionization chamber to investigate pre-earthquake anomalies. The properties of a worldwide data set of 91 radon (^{222}Rn) anomalies have been correlated with earthquake data; these anomalies have been reported as precursors to earthquakes [259]. Changes in water level in wells [260-262], oscillations of water levels [263], an empirical relation between the times and locations of abnormal groundwater changes before the Haicheng earthquake [264], and variation of carbon dioxide content in groundwater [265] have been studied as earthquake precursors.

Anomalous changes of water level, temperature, salinity, electric conductivity, pH, ion concentrations --especially sodium, calcium, magnesium, sulfate, bicarbonate, fluoride, and chloride -- have been measured and their possible relationship to earthquakes reported [266]. The helium concentration of soil gas has been found to decrease before earthquakes [267]. Variations of uranium concentrations and ^{234}U/-^{238}U activity ratios in fault-associated groundwater have been studied [268] for earthquake prediction. Fast Fourier analyses of near-real-time radon data have been carried out [269] in order to determine if any characteristic frequency components are present that can be associated either with precursors to seismicity or with environmental factors. The concentrations of radium-226 in groundwaters [270] as well as Rn anomalies and crustal tilting [271] have been studied as earthquake precursors. Weekly observations of changes in radon content in soil gas using a track etch method have been considered [272] on lines across some faults for earthquake prediction. Variations of the emission rate of mercury and the emanation rate of radon from Earth at an aseismic location have been studied [273]. It is possible that non-seismic-induced variation in gas emission processes has an application in earthquake prediction. The influence of ultrasonic vibration upon microstructure and the emanation of radon from saturated rocks have been discussed [274]. Anomalous infrasound generated by the Alaskan earthquake has been explained [275].

The gravity decrease found close to the Kawanazaki earthquake swarm epicenters has become a clue to the related crustal uplift [276]. Gravity changes before and after an earthquake have been computed [277]. Problems related to earthquake premonitory gravity observations have been discussed [278]. Anomalous variations of seismic energy before large and moderate earthquakes have been studied [279].

The b-value estimated by fitting a set of observed earthquake magnitudes to the magnitude minus frequency relationship, or $\log N(m) = a - bm$ -- where $N(m)$ = number of earthquakes exceeding magnitude m -- have been correlated with the fitting technique used [280]. Changes in b-value -- an increase in b followed by a return to a normal value -- have been noted [281] as an earthquake precursor. Spatial distributions of b-values before large and moderate earthquakes have been studied [282]. A relation between the v-value under tectonic conditions and the stress level of an earthquake region has been discussed [283]. The frequency of occurrence of small earthquakes, variation of the b-value with time, the spatial distribution of small earthquakes, earthquake swarm activity, and variation of the signs of the first motion of small earthquakes have been considered relative to the occurrence of strong earthquakes [284]. The variation of γ-ray intensity before and after earthquakes has been discussed [285].

In generalized models precursive initiation of earthquakes has been explained as a process of generation development and rupture of localized *nonhomogeneity* [286]. The physical process of the fusion of small cracks into larger ones has been discussed [287]; a model for large earthquakes was considered. Certain features observed in the clustering of earthquake sequences have also been studied [288]. A worldwide analysis of the clustering of earthquakes has been carried out [289]; abnormally large clusters indicate an increase in probability of a strong earthquake in three to four years within the same region. Large earthquakes often occur as multiple ruptures reflecting strong variations of stress level along faults [290]. The regularities of formation of a seismic lull region preceding a strong earthquake have been analyzed [291]. The electrically sensitive tuffs close to active faults are useful in earthquake prediction studies [292] provided field sites in partially saturated tuffs can be found. Seismological precursors that have occurred before a magnitude 4.8 earthquake in the northeastern caribbean have been reported [293].

Earthquake swarms appear several months to one or two *years before* and *at about* 100 km distance from impending large earthquakes [294]. Swarms of weak earthquakes have been reported as a long-range precursor [295-298]. Several earthquake swarms at Pavlof Volcano, Alaska, correlated significantly with solid Earth tidal stress rate for periods just before and *after explosive eruptions* [299].

A reservoir analysis of the Denver earthquakes has been considered [300]; earthquakes have been confined to a part of the reservoir where the pressure buildup exceeded 32 bar. This critical value is interpreted as the pressure buildup above which earthquakes occur. The concept of an instability caused by fluid (water) diffusion has been presented [301]. A model to predict reservoir-induced seismicity from reservoir characteristics has been developed [302]. About 1800 earthquakes ($1.4 > M > 4.6$) have filled the 300-m deep reservoir in Tadjikistan; increased seismicity occurred in a series of bursts [303]. The reservoir-induced Koyna earthquake [304] and some earthquakes in China [305] have been studied. Increased hydrothermal activity related to earthquakes has been reported [306]. Ocean-bottom pressure observation have served as a monitoring tool for earthquakes at sea [307]. Reservoir conditions and induced reservoir seismicity at geysers have been studied [308].

Stress-induced piezoelectric fields produce freely propagating electromagnetic radiation when microscopic rock fractures occur in quartz-bearing rocks. An unusual radio emission [309] can have a precursor. Data concerning *seismic sequences* have been used to investigate the time variation of the difference D_1 between the magnitude of a main shock and that of the largest aftershock [310]. The largest earthquakes are associated with low values of the $D_1(t)$ function and a strong seismic activity; earthquakes of $M \geqslant 7.0$ will break out soon *in the Hellenic trench-arc system*. Requirements for reliable prediction of earthquakes have been discussed [311]. Undrained, triaxial-compression, pore pressure experiments have been conducted to monitor pore pressure changes during stick-slip sliding [312]. Time and space characteristics of premonitory anomalies before the *occurrence* of strong earthquakes have been considered [313].

Some geological factors and their influence on seismicity have been discussed [314]. Anomalous crustal deformation [315], variations in hydrochemical constituents [316], and Earth's electrical resistivity close to the surface [317] have been studied to predict earthquakes. Changes in geomagnetic field have been considered as premonitory symptoms of earthquakes [318-321]. Variations of this field have been found to be associated with volcanic eruptions and earthquakes [322]. Geomagnetic and geoelectric studies carried out in the Izu Peninsula and a tectonomagnetic event accompanying the Higashi-Izu earthquake [323] have been discussed. Variations in magnetotelluric resistivities [324] and possible electrical conductivities [325] preceding earthquakes have been studied. A change from two-dimensional geoelectric anisotropy to a more conductive three-dimensional geoelectric configuration during

the period immediately preceding an earthquake has been considered [326].

Microseismicities have been found to be connected with active faults; the different properties of neighboring rocks seem to be the source of microseismicity [327]. Variations of microseism and abnormal increases of ground temperature (80 cm depth) close to the epicentral region before the 1976 Tangshan earthquake have been discussed [328]. Methods for observing natural and induced geophysical fields have been considered for predicting earthquakes [329]. The possibility of short-range prediction of strong earthquakes by considering the pattern of spatial distribution of the surface pressure field has been discussed [330].

An unusual stress transient has been recorded from the epicenter of the Lytle Creek earthquake in southern California [331]. Tectonomagnetic effects associated with aftershocks have been studied by magnetometers [332]. Seismic activity of regions based on a correlation analysis of strong earthquakes and the annual amount of rainfall in epicentral areas has been studied [333]. Some geochemical anomalies observed before some earthquakes and their strong aftershocks have been discussed [334]. Certain aspects of modeling experiments on seismo-geochemical precursors have been described [335]. Sensors for seismological observation and prediction have been described [336]. A model that considers rheological behavior of the crust and seismic belts, mechanisms of stress accumulation, the local stress field, long-term weakening of the crust, time-dependent volume dilatancy, and the possibility of magma intrusion has been studied for the large Tangshan earthquake [337]. The sequence of processes preceding this earthquake -- strain accumulation, land uplift, aseismic creep, inverse land deformation or decrease in creep rate, and earthquake -- has been considered [338]. Possible correlations between the travel-time residual anomaly and the occurrence of earthquakes have been investigated to study the precursory dilatancy stage of the Shillong region [339]. The concept of a unified seismographic process of major earthquakes has been proposed and supported by geodetic data [340]; the significance of this concept with regard to earthquake prediction was discussed.

A statistical method to study unusual seismic activity has been considered [341, 342]. Monitoring of the statistics of a stress drop can reveal precursors of a large earthquake [343]. The driving force causing earthquakes in the North China plain has been modeled numerically by the finite-element method [344]. Seismic data for the period 1446-1969 have been considered to show variation of the activity of the active seismic region; a periodic model and an autoregressional model were used for extrapolation and prediction [345]. Formulas for the time and region of the next large earthquake that will occur within continental China have been established [346]. An analysis of some sequences of earthquakes has been presented [347]; changes in the density distribution function of the stress drop could be an indicator of the preparatory phase of large earthquakes. A statistical study of an earthquake catalog has been used to suggest empirical rules on earthquake prediction in Japan [348]. The spectral characteristics of various small earthquakes previous to a main shock have been studied [349]. A model based on scaling laws that yields a criterion for fragility at different scales and views rupture as a critical point has been considered for a general approach to earthquake prediction [350]. Earth-tilt anomalies before the Haicheng earthquake have been examined [351]; the function of tiltmeters as early-warning predictors of earthquakes has been discussed [352]. Principles of a method for elaboration of a M_{max} (maximum magnitudes of earthquakes) prediction map have been described [353].

A review of the history of earthquake observations in Jamaica has been presented [354]. Seismic parameters of the Tangshan earthquake have been determined; characteristics of the earthquake were discussed [355]. Methods and problems encountered in earthquake prediction with particular reference to the Zaalai event have been studied [356]. A method of probability prediction has been useful in earthquake prediction [357]. A formal

algorithm has been proposed to identify aftershocks following a main event [358]. Earthquake clouds have been discussed [359]; clouds with interference fringes can be used as earthquake precursors.

ANIMAL BEHAVIOR

Some animals can perceive seismic or acoustic waves at low frequency (below 50 Hz), electric field changes, and olfactory stimuli. Some birds and fish are more sensitive than humans to sounds with frequencies below 40 Hz; many animals are exceptionally good at perceiving low frequency vibrations through their skin [360]. Fish possess integumentary sense organs collectively known as the lateral line system. This lateral line is a low frequency sound detector [361]. Some fish are even sensitive to electric field changes as small as 10^{-5} V/m; some laboratory animals also respond to significantly weaker fields than humans. Stimuli caused by the release of gases from small cracks may well be perceived by some animals before earthquakes [360].

Unusual animal behavior prior to some earthquakes has been studied [362-364]. The activities of fish during the aftershock period o: the Tangshan earthquake have been reported [363]. Mean precursory phenomena, both biological and geophysical, have been discussed [365]; mean precursor times for anomalous animal behavior were noted. Abnormal animal and plant behavior was also reported before the Sungpan-Pingwu earthquakes [366].

DISTURBANCES IN THE IONOSPHERE

The effect of subsonic noise from earthquakes on the structure of the spectrum of a high frequency wave reflected from the ionosphere has been studied [367]. The perturbation of the electron concentration in the ionospheric plasma as a result of the action of an acousto-gravitational wave caused by an earthquake has been considered [368]. The response of the ionosphere is related to the effect of the Earth's magnetic field.

CONCLUDING REMARKS

The subject of seismology has advanced considerably during the past few years. Additional studies are needed, however, for a better understanding of the subject.

Certain problems [369, 370] are still of interest to scientists: surface waves in crystalline media (particularly in liquid crystals) under initial stress and application of quantum field theory in the study of seismic problems. Atmospheric radiation generated from seismic surface waves and changes observed in the ionosphere before the occurrence of an earthquake are two topics that should be explored. More attention should be directed toward drawing up a worldwide seismic risk map.

Some geological factors influence seismicity. Correlations between soil temperature measurements and radon activity, as well as between gravity anomalies and earthquakes should be better understood. Geomagnetic and geoelectric investigations should be continued on premonitory symptoms of earthquakes.

The significance of the radon anomaly as a precursor to an earthquake has yet to be established. Permeability in a given field should be studied by comparing radon and carbon dioxide levels.

A number of mechanisms by which seismic energy can be dissipated have been proposed, but further experimental studies using the high pressure and temperature conditions relevant to the mantle is necessary. The vibration analysis and modes of motion of structures during earthquakes -- hence the construction of earthquake-resistant buildings and structures -- should be studied.

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LITERATURE REVIEW: survey and analysis of the Shock and Vibration literature

The monthly Literature Review, a subjective critique and summary of the literature, consists of two to four reviews each month, 3,000 to 4,000 words in length. The purpose of this section is to present a "digest" of literature over a period of three years. Planned by the Technical Editor, this section provides the **DIGEST** reader with up-to-date insights into current technology in more than 150 topic areas. Review articles include technical information from articles, reports, and unpublished proceedings. Each article also contains a minor tutorial of the technical area under discussion, a survey and evaluation of the new literature, and recommendations. Review articles are written by experts in the shock and vibration field.

RECENT PROGRESS IN THE DYNAMIC PLASTIC BEHAVIOUR OF STRUCTURES, PART IV

Norman Jones*

Abstract. This article surveys literature published on the dynamic plastic behavior of structures since the previous review in 1981. It focuses on additional work on the effects of transverse shear and rotatory inertia; recent publications on beams, plates, and shells; and dynamic plastic buckling. Some comments on scaling and structural crashworthiness are included.

Engineering and scientific interest in the dynamic plastic behavior of structures has continued to grow at a rapid pace since the publication of the previous review in 1981 [1]. Earlier reviews were published in this journal in 1975 [2] and 1978 [3]; a more recent review on approximate techniques was published in 1982 [4]. At least five books have been published recently [5-9]. In addition, the **International Journal of Impact Engineering**, launched in 1983, contains articles on the dynamic plastic behavior of structures.

The review published in 1975 [2] concentrated largely on the influences of finite-displacements and material strain rate sensitivity on the dynamic plastic response of structures. Other references [1, 3] discuss various aspects of behavior including ideal fiber-reinforced beams, higher modal response of beams, influence of transverse shear and rotatory inertia, approximate methods of analysis, rapidly heated structures, fluid-structure interaction, dynamic plastic buckling, and numerical studies.

This article is largely concerned with work on the effects of transverse shear and rotatory inertia; recent publications on beams, plates, and shells; and dynamic plastic buckling. Comments on scaling, structural crashworthiness, and other recent work are included.

TRANSVERSE SHEAR AND ROTATORY INERTIA

The influence of transverse shear and rotatory inertia on the dynamic plastic behavior of beams and circular plates was discussed in the previous review [1]. The response of a rigid-plastic beam when struck by a mass at mid-span has been presented more recently [10] for simply-supported and clamped supports. The influence of transverse shear is examined with the aid of square and circular yield criteria that relate transverse shear and bending moment. Oliveira [11] has also studied the behavior of a beam struck by a projectile at mid-span; he included the influence of rotatory inertia as well as transverse shear effects. He found that transverse shear effects are significant and slightly more important for short simply-supported beams than short clamped ones but are almost independent of the support conditions for beams with long spans.

A study has been published [12] on the dynamic response of a simply-supported rigid, perfectly plastic beam subjected to a partly distributed blast-type pressure loading. The influence of transverse shear force is retained in the yield condition. Various patterns of deformation are examined. Some combine plastic bending and shear sliding for a wide range of parameters and time dependence of the dynamic pressure.

Theoretical solutions for the dynamic response of a simply supported cylindrical shell that is impulsively loaded and made from a rigid perfectly plastic material have been developed [13]; rotatory inertia was either neglected or retained in the equilibrium equations. Plastic flow is controlled by a yield condition that includes the transverse shear force as well as the cir-

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cumferential membrane force and longitudinal bending moment.

Rotatory inertia effects were found to be relatively unimportant; a simpler analysis [13] with $I = 0$ would probably suffice for most practical purposes. Furthermore, the calculations also indicated that transverse shear effects have less influence on the maximum permanent transverse displacements of practical cylindrical shells than previously found for impulsively loaded beams and circular plates. Nevertheless, transverse shear effects have a marked effect on the partition of the initial kinetic energy absorbed in the various modes.

BEAMS, PLATES, AND SHELLS

The first part of this section discusses some recent theorems on the dynamic plastic response of structures and continua. The second part emphasizes beams, plates, and shells subjected to lateral or transverse loads. Simple rigid plastic procedures rather than wholly numerical schemes are used.

Martin [14, 15] discussed the ways by which mode shapes might be found in complex rigid-plastic structures that undergo infinitesimal displacements. Ponter [16] has derived a convergence theorem for dynamically loaded structures having a class of viscoplastic constitutive equations that involve internal state variables. The theorem, which is valid for infinitesimal displacements, is illustrated for a simple two-degree-of-freedom structural model.

Several authors have developed theorems for structures that undergo finite lateral or transverse displacements. Ploch and Wierzbicki [17] derived an upper bound on the maximum displacement of impulsively-loaded rigid-plastic continua and structures. The solution of an actual dynamic problem was simplified considerably in this work by replacing it with a statically admissible system of stresses and displacements. A theorem was used to obtain upper bounds for the maximum displacements of a beam and a cylindrical shell, both of which are loaded impulsively over the entire span and simply supported at the ends. The bounds are a considerable improvement over predictions from infinitesimal analyses and gave good estimates for exact solutions that retained the influence of finite displacements in the governing equations.

Stronge [18] obtained a lower bound for the maximum deformation of a rigid-plastic structure subjected to time-dependent loads. This method can be used for finite deformations, or geometry changes, and was illustrated for beams, annular plates, and cylindrical shells. The upper and lower bounds from references [17] and [18], respectively, are compared in Figure 8 of reference [18] with the exact solution for a cylindrical shell subjected to an impulsive velocity.

Van The and Sawczuk [19] obtained a lower bound for the maximum displacement of orthotropic structures loaded impulsively. Their theorem retains the influence of finite displacements and was used to study orthotropic circular plates and orthotropic cylindrical shells.

Reddy [20] has developed a pair of dual extremum principles for a rigid perfectly plastic body subjected to dynamic loads that produce large displacements. However, the extremum principles do not admit moving discontinuities and were not used to examine any structural problems. Thus, it is not yet possible to make an assessment of their accuracy and value.

Griffin and Martin [21] used the instantaneous mode-approximation technique to examine the response of impulsively loaded beams and frames made from a rigid-viscoplastic material. The material is idealized as homogeneous viscous; the influence of finite displacements, or geometry changes, are retained in the governing equations. Griffin and Martin used their procedure to examine the dynamic behavior of a cantilever beam, a portal frame, and a clamped beam. They obtained excellent agreement with previous experimental and theoretical work.

Symonds and Fleming [22] recently examined the behavior of a cantilever beam

with a tip mass that is subjected to a short pulse loading. They observed that the initial traveling-hinge phase for a rigid-plastic idealization of this particular elastic-plastic problem is essentially a fiction. However, the subsequent mode form phase is a prominent and significant feature of the late-time part of the actual elastic-plastic response.

The influence of a falling mass striking a fully clamped beam was studied by Oliveira [23]. He presented various equations for the design of steel offshore structures against impact loads. Oliveira [23] also presented formulas that are suitable for the design of rectangular plates struck by falling objects.

The stability of the response of a simply-supported rigid-plastic beam subjected to an initial impulsive velocity having a second modal shape has been discussed [24]. Martin and Lloyd [25] also examined convergence onto higher modes in impulsively-loaded rigid perfectly-plastic beams.

Lepik [26-28] studied the optimal design of rigid-plastic beams subjected to impulsive velocities or dynamic pressure loadings.

Various studies have been reported on the dynamic plastic behavior of beams [29-33] and the response of portal frames [34, 35]. A simple scheme has been outlined for determining maximum and final displacements of elastic-plastic structures subjected to pulse loadings of arbitrary length [36]. The method is illustrated for a fixed-base portal frame subjected to a load applied at mid-height of one column.

Symonds and Wierzbicki [37] neglected bending moments and retained only membrane forces in the basic equations for an impulsively loaded clamped circular plate. They achieved good agreement with test results on steel and titanium plates provided they considered the influence of material strain rate sensitivity. However, they found relatively poor agreement with tests on lead plates. Moreover, it has been shown [38] that certain theoretical predictions [37] do not give good agreement with the corresponding experimental results on aluminium 6061 T6 circular plates. The simple theoretical work of Guedes Soares [38] is based on earlier studies on plates [39].

The dynamic response of circular membranes with large deflections has also been studied [40, 41].

Joubert [42] examined the damage suffered by the bottom plating of yachts and used a rigid-plastic theory to estimate the pressure generated during slamming in heavy weather.

Reid [43] reported some experimental tests on the response of ring and tube systems subjected to lateral impact loads and emphasized the importance of inertia effects. Reid and Austin [44] have further clarified the nature of inertia effects on the collapse modes for two classes of structure. Results of experimental tests on ring and tube systems subjected to dynamic lateral loads, development of a structural shock wave theory, and comments on the importance of several factors including material strain rate sensitivity are available [45-48]. Reid [47] showed that an understanding of inertia effects can be utilized to modify a basic ring system to obtain a response suitable for particular design requirements.

A testing procedure for applying dynamic biaxial, tension-internal pressure loading to thin-walled aluminium 6061 T6 tubes with strain rates up to about 100 sec^{-1} has been developed [49]. Initial dynamic yielding occurred at a higher state of biaxial stress than static yielding; the increase depended on the loading rate. The average dynamic fracture hoop stress was found to be about 1.62 times the corresponding static value.

DYNAMIC PLASTIC BUCKLING

The phenomenon of dynamic plastic buckling has been discussed [1-3]. A recent article [50] surveys the published literature on columns, rings, cylindrical shells, spherical shells, and spherical caps. Lindberg and Florence [51] have also prepared a comprehensive review of dynamic elastic and plastic pulse buckling and provided a

summary of theoretical contributions over the past two decades.

The dynamic axisymmetrical behavior of a perfect complete spherical shell made from a bilinear or work hardening material and subjected to a uniform external step pressure loading has been investigated [52]. A perturbation method of analysis was used to obtain a Mathieu equation that gives the dynamic buckling pressure and associated mode for a complete spherical shell. The influences of the plastic parameter and damping on the dynamic buckling pressure and mode number were also examined.

The dynamic elastic buckling pressure was about 0.36 of the corresponding static elastic buckling pressure; the associated dynamic buckling mode number was about 0.70 of the corresponding static elastic buckling mode number [52]. The dynamic elastic-plastic buckling pressure was less than the dynamic elastic buckling pressure; the elastic-plastic buckling mode number was smaller than the static elastic-plastic buckling mode number for the parameters examined.

An experimental study on the dynamic axial plastic buckling of cylindrical shells has been reported [53]. Several investigators have examined the buckling of columns or rods subjected to dynamic axial loads [54-56].

SCALING

The subject of scaling was not considered in three previous reviews [1-3] largely because, at that time, it was thought Duffey [57] had demonstrated that, under certain circumstances, geometrical scaling was possible for the dynamic plastic behavior of structures except for well-known material strain rate sensitivity effects. However, recent studies, which have been summarized [58, 59], have seriously questioned the laws that relate the dynamic inelastic behavior of small-scale model structures and full-size prototypes. Drop tests on welded plate structures have revealed a significant departure from elementary scaling laws; the damage of a prototype was considerably greater than that anticipated from experimental tests on a geometrically similar model [60]. Another recent study has encountered somewhat similar difficulties with tests on ship structures [61].

A series of 13 drop tests on one-quarter scale to full-scale thin plated mild steel and stainless steel structures has been reported [60]. The specimens were as geometrically similar as possible and were subjected to the same impact velocity; such a criterion is required for elementary scaling. The permanently deformed shapes of the specimens should, therefore, be geometrically similar, but significant departures from similitude occurred [60]. In fact, the authors found that the post-impact deformations might be as much as 2.5 times greater in a full-scale mild-steel prototype than would be expected from the extrapolated results obtained on a one-quarter scale model.

It was observed that weld fracture and tearing were considerably more pronounced in the full-scale eggbox and plate girder specimens than in the smaller ones. Furthermore, deviation from the elementary scaling laws was greater for the mild steel eggbox type structures than the stainless steel ones.

Tests have recently been reported on three sets of geometrically similar beams made from steel plates with thicknesses of 2.3 mm, 6 mm, and 20 mm and subjected to static loads [61]. The results indicated a significant reduction in ductility as plating thickness increased, particularly for beams with a 20 mm plate having a notch. However, the true differences were masked because the stress-strain characteristics of the three plate thicknesses differed. These experimental results [61] were replotted [58]. The various curves now properly account for the different material characteristics, although a definite pattern can still be discerned; the beam with a 20 mm thick notched plate still shows a much reduced capacity. A significant departure from elementary scaling was found when experimental results [61] were replotted [58].

Valsgard and Pettersen [62, 63] incorporated into their numerical studies a crack opening displacement criterion of fracture mechanics (COD) for the side shell rupture of ships involved in collisions with other ships or marine structures. This method is potentially capable of accounting for the change in ductility with thickness, strain rate, and temperature; it can also be used to assess the influence of internal defects and cracks as well as to recognize differences in plating quality. Pettersen and Valsgard [63] used a COD design curve that requires toughness tests to be performed on the full-thickness plating in order to obtain the critical COD value.

The authors used their method to study the 17 mm thick side shell of a ship. They found an associated rupture strain of about five percent when they accounted for the statistics of internal defects. This contrasts with a rupture strain of about 60 percent obtained [63] for a 1.62 mm thick plate used by other authors for structural model tests of ships.

Calladine [64] showed that the size effect associated with material strain rate sensitivity -- the effect arises from the elementary scaling requirement of constant impact velocity at different scales -- is exacerbated in the presence of nonlinear load-displacement characteristics.

Experimental tests on the dynamic cutting of mild steel have been conducted on a drop hammer rig [59]. Heavy solid wedges were made from mild steel; the wedges were case hardened and attached to the head of a variable mass tup. The mild steel plate specimens were clamped along the bottom edge and both vertical sides in a rigid frame that was secured vertically to the base of the drop hammer rig. The large specimens absorbed less energy for a given scaled penetration than would be predicted from the behavior of small specimens according to the principles of elementary geometrical scaling. For example, the deformations of a prototype were 2.283 times larger than those predicted from a one-quarter scale model according to the principles of elementary geometrical scaling.

Other experimental results [60] showed that the permanent deformation of the prototype mild steel eggbox specimen was 2.45 times larger than a geometrically scaled prediction from a one-quarter scale model. The stainless steel results were 1.85 times larger for a similar scale factor. There is a remarkable measure of agreement between the significant departures from the principles of geometrically similar scaling observed in the two quite different sets of experimental tests [59, 60].

Other investigators have discussed various aspects of the scaling laws [65-67]. Scaling laws for punch-impact response of structures, including elastic-plastic effects and ductile fracture, have been reported [65]. Full-scale and one-half-scale punch experiments on mild steel and stainless steel plates were generally within ten percent of expected values. The deflections were somewhat larger and the energy absorbed somewhat smaller for the full-scale prototype than the respective scaled values from the one-half scale model.

STRUCTURAL CRASHWORTHINESS

Many papers have been written on the topic of structural crashworthiness; books [7, 68] and the proceedings of the First International Symposium on Structural Crashworthiness at the University of Liverpool [69, 70] contain a conspectus and introduction to the main body of this work. Impact velocities in this field are often considered sufficiently slow that the structural response can be taken as quasi-static although material strain rate sensitivity effects must be retained [71]. On the one hand, the neglect of inertia considerably simplifies theoretical analyses; on the other hand, complexity arises because large plastic strains and deflections develop during the structural response.

The behavior of thin-walled tubes with circular and rectangular cross sections and subjected to axial loads has been of particular interest since the pioneering work of Pugsley [72] on the impact of idealized railway coaches. Thin-walled members with closed hat and rectangular cross sec-

tions are relevant to the energy absorption characteristics of automobile body structures as well as trains and buses. The initial buckling response of these members is less important from the viewpoint of energy absorption than the subsequent postbuckling behavior with large strains and deflections. This behavior is often idealized as rigid plastic because the energy absorbed elastically is usually not significant. Optimal energy absorption is achieved through progressive buckling that avoids overall, or Euler, buckling [73, 74].

A simplified kinematical method of analysis that can be used to estimate the crushing characteristics of thin-walled structures has been developed [75-78]. Some studies [76, 77] focused on the behavior of two basic folding or collapse elements. The importance of this theoretical procedure lies in its rigorous kinematical approach and the retention of extensional as well as bending contributions to the energy dissipation. Basic collapse elements have been used to predict the axial collapse behavior of a cruciform member [76], the behavior of a honeycomb [79], and one kind of collapse (symmetric) of rectangular and square box columns [77]. Extensional deformations, though highly localized, dissipated at least one-third of the total energy.

Theoretical studies on basic collapse elements for the crushing behavior of thin-walled sections [76, 77] have been used to derive various progressive crushing modes for square tubes loaded axially [80]. This theory predicts four deformation modes that govern the behavior of different ranges of the parameter c/h. New asymmetric deformation modes were predicted theoretically and confirmed in experimental tests. These asymmetric modes cause inclination of a column that could lead to collapse in the Euler sense for even relatively short columns.

It has recently been shown [81] that the effective crushing distance is 70 percent of the initial length for axially crushed box columns undergoing a symmetric deformation mode. This value was obtained by idealizing the corner collapse of a box column and assuming that the deformations resulted from bending about two orthogonal axes. A theoretical analysis [80] for the axial crushing of square box columns considers the effective crushing distance and the influence of material strain rate sensitivity; the latter is important for steel even when dynamic loadings can be treated as quasi-static [71]. Simple equations [80] gave reasonable agreement with corresponding experimental results on axially crushed square box columns.

A modified version of a theoretical analysis for axisymmetric, or concertina, deformations of axially crushed cylindrical shells [82] has been developed [83] and gives good agreement with experimental results when the effective crushing distance is considered and provided that the influence of material strain rate sensitivity is retained in the dynamic crushing case. Experimental results from static and dynamic axial crushing tests on circular and square steel columns [80, 83] have been discussed [84] and compared with previously published experimental results [74, 85-87] and with various empirical relations and theoretical predictions.

Some work on the energy absorption of structural members has been reviewed [7, 68-70, 88]. Several papers have considered aspects of car design and human injury [89, 90]; others have discussed the protection of car occupants in frontal impacts with heavy lorries [91]. Johnson and Walton [92] examined fires in public service vehicles and concluded that a catastrophic collision with a petrol tanker, for example, is possible. The structural response of petrol tankers and other road transport tank vehicles subject to internal explosion or static penetration has been studied [93].

Some aspects of aircraft crashworthiness have been examined [7, 94]. Road, rail, ship, offshore platform, and airship collisions have also been discussed [7].

NUMERICAL STUDIES

A section on numerical studies was included in three previous reviews [1-3]. Articles that have more recently come to the

author's attention are briefly discussed in this section.

Chon and Weng [95] examined the response of a finite bar subjected to an axial impact using a finite-difference method. The numerical scheme considered material elasticity, plasticity, and strain rate sensitive effects. It was used to assess behavior when the end of a rod is struck axially by a mass traveling with an initial velocity. The authors studied the features of stress wave propagation and compared their results with several approximate theories that use simplified constitutive equations. Significantly different permanent strains were associated with different constitutive equations.

Lepik and Just employed a numerical scheme [96] to obtain the response of rigid-plastic stepped beams with various support conditions and subjected to impulsive or dynamic pressure loading. Samuelides and Frieze [97] developed a finite-difference procedure to study the elastic-plastic behavior of a beam subjected to dynamic loads that produce large transverse or lateral displacements. Shieh [98] examined the importance of material strain hardening and viscoplastic effects on the dynamic response of frames.

Several investigators [99-101] have developed numerical schemes to obtain the behavior of rectangular plates subjected to dynamic lateral loads. Good agreement has been predicted with experimental results [100, 101] on impulsively loaded rectangular plates [102]. Ni [100] also examined the behavior of circular plates; Toi and Kawai [101] studied the dynamic response of cylindrical and spherical shells.

MISCELLANEOUS STUDIES

The interaction between long rods or projectiles and rigid and soft targets has been studied [103-106]. Plasticine [103, 104] for both rod and target is attractive and permits a study of the phenomena to be undertaken cheaply, quickly, and safely in a small laboratory. Neilson [107] reported experiments on cylindrical missile impact on square, circular, and triangular target panels. Various aspects of the perforation of plates have also been considered [108-113].

Several authors [114-117] have studied the missile and blast impact of reinforced concrete structures. Kolsky and Mosquera [118] made fiber-reinforced beams using steel piano wires embedded in metal matrices of lead and lead tin alloys. Dynamically loaded specimens were found to exhibit some of the features predicted by ideal fiber-reinforced rigid-plastic theories [3].

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BOOK REVIEWS

FLUID TRANSMISSION LINE DYNAMICS

M.E. Franke and T.M. Drzewiecki, Eds.
ASME Publ. H00278, New York, NY
1983, 138 pages, $30.00

This book is a collection of seven papers on fluid transmission line dynamics presented at the ASME 1983 Winter Annual Meeting. The first volume with the same title was published by ASME in 1981.

The purpose of this field of study is to determine amplitudes and phases of dependent variables -- such as pressure and discharge rate -- of fluid transmission lines as functions of position and either frequency or time. The analysis of fluid transmission line dynamics deals primarily with fluid oscillation based on linear vibration theory and electric transmission line theory. The key equations governing fluid transmission line dynamics are a pair of transfer equations for pressure and discharge rate. The transfer coefficients of these equations consist of hydraulic impedance and hyperbolic functions of the propagation operator. For exact analysis models both the propagation operator and impedance involve the Bessel function ratio.

The first paper compares the mathematical theory for fluid transmission line dynamics using various source and load impedances against experimental data. The second paper presents a first-order square-root approximation to the Bessel function ratio for the solution of the transfer equations. The third paper uses rational polynominal approximations for both Bessel functions and hyperbolic functions. The fourth paper presents a time domain simulation of fluid transmission line dynamics using minimum-order state-variable models. The fifth paper compares the explicit method of characteristics, implicit methods, analog simulation, and small signal linearization techniques for various load and valve characteristics. The sixth paper discusses the effect of transmission line dynamics on the response of servo-controlled actuators. The last paper describes the effects observed on discrete-frequency pressure-pulsation response levels caused by varying acoustic load impedances individually at the suction port and the discharge port of a volute pump.

The papers reflect continuing interest in fluid transmission line dynamics. They contain the results of delicated research work and cover both experimental data and numerical solution techniques. The book should benefit university and industry researchers who are already familiar with the background theory.

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FUNDAMENTALS OF SOIL DYNAMICS

B.M.Das
Elsevier Scientific Publ. Co.,
Amsterdam and New York
1983, 400 pages, $39.50

Braja M. Das does a good job of introducing various aspects of soil dynamics. The 11 chapters cover fundamentals of vibrations; stress waves in one, two, and three dimensions; air blast loading on the ground; analysis of foundation vibrations; dynamic bearing capacity of shallow foundations; earthquake and ground vibrations; lateral earth pressure on retaining structures; compressibility of soils under dynamic loading; and liquefaction of saturated sands. The book does not cover pile foundations. Machine foundations are included in the chapter on

compressibility of soils under dynamic loads. Dynamic stress deformation and strength characteristics are also somewhat camouflaged in the chapter on stress waves in bounded elastic medium.

This text appears to have been prepared for those geotechnical engineers who have not been introduced to any structural dynamics. Such introductions are typical at most undergraduate schools these days. Thus, the book is a good reference for practicing engineers who want to use it for continuing education and to learn new material. The book will also be useful to engineering managers who want an introduction to the fundamentals of soil dynamics.

The subject of soil dynamics is so dynamic that it is difficult indeed to keep abreast of the latest research. However, there is yet another dilemma: those seriously engaged in analyzing problems related to soil dynamics and geotechnical earthquake engineering are keeping the state-of-the-art reasonably close to the latest research. In view of these facts, it can be said that Das has taken only a first step.

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SEISMIC MIGRATION. IMAGING OF ACOUSTIC ENERGY BY WAVE FIELD EXTRAPOLATION. A THEORETICAL ASPECT

A.J. Berkhout
Elsevier Scientific Publ. Co.,
Amsterdam and New York
1982, 352 pages, $59.50

This excellent book deals with the problem of seismic imaging. The author has made significant contributions in this field, particularly in the area of wave-field extrapolation.

The author presents in a concise manner various techniques used to study seismic migration. The underlying theory is derived from first principles; the book is thus useful as a text on seismic migration theory. The author has successfully collected material that has been published in other books and in journals. The book will also serve as a valuable reference for researchers and practitioners in the field.

The book is divided into 11 chapters and contains five appendices. The first five chapters deal with vector analysis, spectral analysis, Fourier transforms, acoustic wave theory, and the Kirchhoff integral. Forward and inverse wave-field extrapolations are dealt with in Chapters 6 and 7. Wave-number-frequency domain migration and summation and finite-difference approaches to migration are discussed in Chapters 8, 9, and 10. Seismic modeling and migration techniques are summarized and compared in the final chapter. In this very useful chapter the author discusses the possibilities and limitations of each technique in practical applications. The appendices deal with details of algebra and derivations of governing equations.

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MECHANICAL VIBRATIONS FOR ENGINEERS

M. Lalanne, P. Berthier, and
J. Der Hagopian
John Wiley and Sons, New York, NY
1983, 266 pages, $15.95

This book is a revision of Mechanique des Vibration Lineaires published in French by Masson in 1980. Dean Frederick C. Nelson of Tufts University ably provided the English translation. According to the authors the purpose of the book is to provide engineering students and practitioners with an understanding of

vibration phenomena and concepts; the ability to formulate and solve the equations of motion of vibrating systems; and an appreciation of the role and technique of vibration measurement.

At the outset it seems clear that the book is not for beginning students in vibration. Students and practitioners alike should have been exposed to a good fundamental course in linear vibrations prior to using this book. Although the book is easy to read and is understandable, it does not provide the thorough treatment of vibration necessary for a beginning text. It does, however, provide a clear and useful reference for anyone who is concerned with solving vibration problems.

The book contains seven chapters and an Appendix explaining Lagrange's equations. Chapter 1 uses single-degree-of-freedom systems to provide a good introduction to vibration phenomena such as resonance, damping, and forced response. Rayleigh's method for approximating the lowest frequency of free vibration for an undamped system is introduced. Most importantly, Chapter 1 shows that single-degree-of-freedom systems can frequently be used as a convenient early approximation to a real structure. Two applications are described to illustrate first order models representing vehicle suspensions or isolators and accelerometers.

Chapter 2 discusses both undamped and damped two-degree-of-freedom systems involving free and forced vibration. The authors use this chapter as an opportunity to introduce the modal method, even though direct calculations would have been simpler. This chapter also discusses the principle of a vibration absorber.

Having laid the groundwork in the previous chapter, the authors proceed to elaborate in Chapter 3 the modal method for N-degree-of-freedom systems. They assume some knowledge of matrix algebra in their discussion of the concepts of mass, stiffness, and damping matrices. Modal properties essential to the method, such as orthogonality, modal mass, and modal stiffness, are described. Methods presented for calculating frequencies and modes include the direct method, the Rayleigh-Ritz method, and an iterative method. Finally, methods for calculating the steady-state response and general response of N-degree-of-freedom systems to excitation are discussed.

Chapters 4 and 5 bring the reader face-to-face with problems involving real systems. Analytical solutions for practical structures are usually complicated and laborious; hence the authors stress numerical solutions. In Chapter 4 the Rayleigh-Ritz method is emphasized; in Chapter 5 the finite element method is used. In both chapters a reader with a reasonable background is able to understand the solutions without great difficulty.

Chapter 6 provides a change of pace in that it introduces the reader to current equipment and techniques used for vibration measurement. Although the treatment is fairly brief, it provides a good point of departure for further studies.

Chapter 7 is extremely useful. The 12 computer programs presented can be used on a microcomputer with at least 16K bytes of core memory. The programs are written in BASIC and provide reference solutions to several types of vibration problems. Program 9, for example, is for solving the frequencies of a beam in bending, modal masses and stiffness, modes, deflection, slope, and maximum stress. These computer programs should also provide beginners with a chance for some experience with the dynamic behavior of multi-degree-of-freedom structures without the difficulty of lengthy hand calculation.

Another useful aspect of the book is that it contains more than 100 problems and exercises, many of which represent problems of practical interest. Working through these exercises is probably the single best way to learn. Answers are given for all problems, and most of the solutions are given in some detail.

A table of symbols would have been useful in clarifying some of the notation early on. Otherwise, in general, the book will

be an extremely useful reference. It combines several aspects of dealing with vibration problems in a way that has not been done before.

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STRUCTURAL ANALYSIS

A. Chajes
Prentice Hall, Inc., Englewood Cliffs, NJ
1983, 361 pages, $28.95

This book is an introduction to structural *analysis and finite elements* (FE). The author uses examples to explain applications of the various methods described. As stated by the author, "The aim of this book is to present the fundamentals of structural analysis and to serve as a textbook for one or more courses on the subject."

The book consists of 16 chapters and an appendix on the explanation of matrix analysis and algebra. Chapter 1 introduces structural analysis and considers the materials and loads used in structural engineering. Chapter 2 contains calculations of reactions of simple and complex structures and equations of equilibrium and types of supports and restraints. Chapter 3 focuses on plane trusses, including simplifying assumptions and basic concepts. Chapter 4 briefly discusses solving space truss problems by calculating reactions and member forces.

The next chapter is about shear and moment diagrams for beams and frames. The author uses the accepted sign conventions for forces and moments. Shear and bending moment diagrams are constructed using the method of sections. The relationships among load, shear, and bending moments are developed. Chapter 6 describes deflections using differential equations; solutions of direct integration, moment area, conjugate beam methods, and applications are given.

Chapter 7 summarizes energy methods used in solving deflections. Included are principles of conservation of energy, methods of real work, and an explanation of virtual work as they are used in beams, frames, and trusses. The next chapter defines influence lines and their application to beams and trusses. The determination of moments from influence lines is given. Chapter 9 contains brief discussions of the solution of moments and shears of two and three hinged arches and the determination of forces in cables.

The next chapter introduces indeterminate structures. Chapter 11 elaborates the concept of the method of consistent deformations. The next chapter focuses on the method of least work; this method is considered the heart of indeterminate structural analysis. Castigliano's first and second theorems are derived. Reactions are determined for a simple beam, a tension wire supported beam, a truss, and a closed ring.

Chapter 13 applies slope deflection to the solution of indeterminate structures. The author uses the slope deflection method to determine the shears and moments of statically indeterminate structures. He applies it to complex beams and frameworks. Chapter 14 discusses the moment distribution method, which is *rarely seen* in modern texts of structural analysis. It is essentially an iterative process in which joint rotations and displacements are used. Applications are given for structures with and without joint translations. This is a good introductory chapter.

Chapter 15 has to do with matrix flexibility. The derivation of the flexibility matrix, formulation of the structure-flexibility matrix, and the force-transformation matrix are given. The chapter concludes with analysis and application of an indeterminate beam and framework structure.

The last chapter is on the widely used matrix stiffness method. The most desirable feature of this method is the ease with which it can be programmed on a digital computer. The author derives the element stiffness matrix for axial and flexural elements and combires them in an element-stiffness matrix. A derivation of

an alternate approach, called the direct stiffness method, is the more commonly used derivation of the stiffness matrix. It is called finite element method (FE). The chapter concludes with applications to flexural structures and trusses containing members directed at an angle to the horizontal. Digital computer programs of the FE and flexibility approach could be used in the analysis of beams and frames.

This is a good book; some sections are elementary, but the book is easy to read and understand. One criticism is the lack of references. The other notable missing features are descriptions of shear deformation in beams and transfer matrices as alternates to stiffness and flexibility matrices. More examples should have been included to show applications of Maclaurin's series of singularity functions in the determination of the deflections of a beam. The experienced reader can benefit by reviewing some of the various concepts, notably moment distribution, which is deleted in most present day texts. The reviewer recommends this book to designers and analysts in structural engineering.

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1 Arcadian Drive
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SHORT COURSES

MARCH

MECHANICAL ENGINEERING

Dates: March 4-8, 1985
Place: Carson City, Nevada
Dates: August 12-16, 1985
Place Carson City, Nevada
Objective: This course is designed for mechanical, maintenance, and machinery engineers who are involved in the design, acceptance testing, and operation of rotating machinery. The seminar emphasizes the mechanisms behind various machinery malfunctions. Other topics include data for identifying problems and suggested methods of correction.

Contact: Customer Information Center, Bently Nevada Corporation, P.O. Box 157, Minden, NV 89423 - (702) 782-3611, Ext. 9243.

VIBRATION AND SHOCK SURVIVABILITY, TESTING, MEASUREMENT, ANALYSIS, AND CALIBRATION

Dates: March 11-13, 1985
Place: Washington, D.C.
Dates: May 6-10, 1985
Place: Boston, Massachusetts
Dates: June 3-7, 1985
Place: Santa Barbara, California
Dates: August 26-30, 1985
Place: Santa Barbara, California
Dates: December 2-6, 1985
Place: Santa Barbara, California
Objective: Topics to be covered are resonance and fragility phenomena, and environmental vibration and shock measurement and analysis; also vibration and shock environmental testing to prove survivability. This course will concentrate upon equipments and techniques, rather than upon mathematics and theory.

Contact: Wayne Tustin, 22 East Los Olivos Street, Santa Barbara, CA 93105 -(805) 682-7171.

MACHINERY INSTRUMENTATION

Dates: March 12-14, 1985
Place: Edmonton, Alberta, Canada
Dates: April 16-18, 1985
Place: Philadelphia, Pennsylvania
Dates: May 14-16, 1985
Place: San Francisco, California
Dates: June 25-27, 1985
Place: Denver, Colorado
Dates: November 12-14, 1985
Place: Calgary, Alberta, Canada
Objective: This seminar provides an in-depth examination of vibration measurement and machinery information systems as well as an introduction to diagnostic instrumentation. The three-day seminar is designed for mechanical, instrumentation, and operations personnel who require a general knowledge of machinery information systems. The seminar is a recommended prerequisite for the Machinery Instrumentation and Diagnostics Seminar and the Mechanical Engineering Seminar.

Contact: Customer Information Center, Bently Nevada Corporation, P.O. Box 157, Minden, NV 89423 - (702) 782-3611, Ext. 9243.

PENETRATION MECHANICS

Dates: March 18-22, 1985
Place: San Antonio, Texas
Objective: This course presents the fundamental principles of penetration mechanics and their application to various solution techniques in different impact regimes. Analytical, numerical, and experimental approaches to penetration and perforation problems will be covered. Major topic headings of the course are: fundamental relationships, material considerations, penetration of semi-infinite targets, perforation of thin targets, penetration/perforation of thick targets, hydrocode solution techniques, experimental techniques. Discussions will include such topics as fragment or projectile breakup, obliquity, yaw, shape effects, and richo-

chet. Shock propagation, failure mechanisms and modeling, constitutive relations, and equation-of-state will be presented in the context of penetration mechanics. Developed fundamental relationships will be applied in the following areas: hypervelocity impact, long rod penetration; spaced and composite armors, explosive initiation, hydrodynamic ram, fragment containment, earth penetration, crater/hole size, spallation, shaped charge penetration.

Contact: Ms. Deborah J. Stowitts, Southwest Research Institute, 6220 Culebra Road, San Antonio, TX 78284 -(512) 684-5111, Ext. 2046.

MACHINERY INSTRUMENTATION AND DIAGNOSTICS

Dates: March 19-22, 1985
Place: Orlando, Florida
Dates: March 26-29, 1985
Place: Syracuse, New York
Dates: May 6-10, 1985
Place: Carson, Nevada
Dates: June 4-7, 1985
Place: Pittsburgh, Pennsylvania
Dates: July 15-19, 1985
Place: Carson City, Nevada
Dates: September 10-13, 1985
Place: New Orleans, Louisiana
Dates: September 24-27, 1985
Place: Anaheim, California
Dates: October 8-11, 1985
Place: Philadelphia, Pennsylvania
Dates: October 21-25, 1985
Place: Carson City, Nevada
Dates: November 5-8, 1985
Place: Boston, Massachusetts
Dates: December 3-6, 1985
Place: Houston, Texas

Objective: This course is designed for industry personnel who are involved in machinery analysis programs. Seminar topics include a review of transducers and monitoring systems, machinery malfunction diagnosis, data acquisition and reduction instruments, and the application of relative and seismic transducers to various types of rotating machinery.

Contact: Customer Information Center, Bently Nevada Corporation, P.O. Box 157, Minden, NV 89423 - (702) 782-3611, Ext. 9242.

VIBRATION CONTROL

Dates: March 25-29, 1985
Place: Manassas, Virginia
Dates: June 3-7, 1985
Place: San Diego, California

Objective: This vibration control course will include all aspects of vibration control except alignment and balancing. (These topics are covered in separate Institute courses.) Specific topics include active and passive isolation, damping, tuning, reduction of excitation, dynamic absorbers, and auxiliary mass dampers. The general features of commercially available isolation and damping hardware will be summarized. Application of the finite element method to predicting the response of structures will be presented; such predictions are used to minimize structural vibrations, during the engineering design process. Lumped mass-spring-damper modeling will be used to describe the translational vibration behavior of packages and machines. Measurement and analysis of vibration responses of machines and structures are included in the course. The course emphasizes the practical aspects of vibration control. Appropriate case histories will be presented for both isolation and damping.

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 West 55th Street, Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

MODAL TESTING OF MACHINES AND STRUCTURES

Dates: March 26-29, 1985
Place: Manassas, Virginia
Dates: August 13-16, 1985
Place: Nashville, Tennessee

Objective: Vibration testing and analysis associated with machines and structures will be discussed in detail. Practical examples will be given to illustrate important concepts. Theory and test philosophy of modal techniques, methods for mobility measurements, methods for analyzing mobility data, mathematical modeling from mobility data, and applications of modal test results will be presented.

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 West 55th Street, Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

APRIL

MACHINERY RISK MANAGEMENT

Dates: April 15-17, 1985
Place: Carson City, Nevada
Objective: This course is a sequel to a risk seminar presented two years ago in Carson City, Nevada. It is designed to update insurance/risk managers on recent developments in predictive maintenance and diagnostic programs for rotating machinery.

Contact: Customer Information Center, Bently Nevada Corporation, P. O. Box 157, Minden, NV 89423 - (702) 782-3611, Ext. 9243.

MACHINERY VIBRATION ANALYSIS AND CONTROL

Dates: April 23-26, 1985
Place: Cincinnati, Ohio
Objective: This course emphasizes the role of vibrations in mechanical equipment instrumentation for vibration measurement, techniques for vibration analysis and control, and vibration correction and criteria. Examples and case histories from actual vibration problems in the petroleum, process, chemical, power, paper, and pharmaceutical industries are used to illustrate techniques. Participants have the opportunity to become familiar with these techniques during the workshops. Lecture topics include: spectrum, time domain, modal, and orbital analysis; determination of natural frequency, resonance, and critical speed; vibration analysis of specific mechanical components, equipment, and equipment trains; identification of machine forces and frequencies; basic rotor dynamics including fluid-film bearing characteristics, instabilities, and response to mass unbalance; vibration correction including balancing and alignment; vibration control including isolation and damping of installed equipment; selection and use of instrumentation; equipment evaluation techniques; steam turbine balancing; and plant predictive and preventive maintenance. This course will be of interest to plant engineers and technicians who must identify and correct faults in machinery.

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 West 55th Street, Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

MAY

ROTOR DYNAMICS

Dates: May 6-10, 1985
Place: Syria, Virginia
Objective: The role of rotor/bearing technology in the design, development and diagnostics of industrial machinery will be elaborated. The fundamentals of rotor dynamics; fluid-film bearings; and measurement, analytical, and computational techniques will be presented. The computation and measurement of critical speeds vibration response, and stability of rotor/bearing systems will be discussed in detail. Finite elements and transfer matrix modeling will be related to computation on mainframe computers, minicomputers, and microprocessors. Modeling and computation of transient rotor behavior and nonlinear fluid-film bearing behavior will be described. Sessions will be devoted to flexible rotor balancing including turbogenerator rotors, bow behavior, squeeze-film dampers for turbomachinery, advanced concepts in troubleshooting and instrumentation, and case histories involving the power and petrochemical industries

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 West 55th Street, Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

AUGUST

MACHINERY VIBRATION ANALYSIS

Dates: August 13-16, 1985
Place: Nashville, Tennessee
Dates: Oct. 29 - Nov. 1, 1985
Place: Oak Brook, Illinois
Objective: This course emphasizes the role of vibrations in mechanical equipment instrumentation for vibration measurement, techniques for vibration analysis and control, and vibration correction and criteria. Examples and case histories from actual vibration problems in the petroleum, process, chemical, power, paper, and pharma-

ceutical industries are used to illustrate techniques. Participants have the opportunity to become familiar with these techniques during the workshops. Lecture topics include: spectrum, time domain, modal, and orbital analysis; determination of natural frequency, resonance, and critical speed; vibration analysis of specific mechanical components, equipment, and equipment trains; identification of machine forces and frequencies; basic rotor dynamics including fluid-film bearing characteristics, instabilities, and response to mass unbalance; vibration correction including balancing; vibration control including isolation and damping of installed equipment; selection and use of instrumentation; equipment evaluation techniques; shop testing; and plant predictive and preventive maintenance. This course will be of interest to plant engineers and technicians who must identify and correct faults in machinery.

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 West 55th Street, Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

BALANCING OF ROTATING MACHINERY
Dates: August 13-16, 1985
Place: Nashville, Tennessee
Objective: This course will emphasize the practical aspects of balancing in the shop and field including training on basics, the latest techniques, and case histories. The instrumentation, techniques, and equipment pertinent to balancing will be elaborated with case histories. Demonstrations of techniques with appropriate instrumentation and equipment are scheduled. Specific topics include: basic balancing techniques (one- and two-plane); field balancing; balancing machines and facilities; use of programmable calculators; turbine-generator balancing; balancing sensitivity; factors to be considered in high speed balancing; effect of residual shaft bow on unbalance; tests on balancing machines; flexible rotor balancing --training and techniques; a unified approach to flexible rotor balancing; and coupling balancing.

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 West 55th Street, Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

OCTOBER

VIBRATIONS OF RECIPROCATING MACHINERY
Dates: Oct. 29 - Nov. 1, 1985
Place: Oak Brook, Illinois
Objective: This course on vibrations of reciprocating machinery includes piping and foundations. Equipment that will be addressed includes reciprocating compressors and pumps as well as engines of all types. Engineering problems will be discussed from the point of view of computation and measurement. Basic pulsation theory --including pulsations in reciprocating compressors and piping systems -- will be described. Acoustic resonance phenomena and digital acoustic simulation in piping will be reviewed. Calculations of piping vibration and stress will be illustrated with examples and case histories. Torsional vibrations of systems containing engines and pumps, compressors, and generators, including gearboxes and fluid drives, will be covered. Factors that should be considered during the design and analysis of foundations for engines and compressors will be discussed. Practical aspects of the vibrations of reciprocating machinery will be emphasized. Case histories and examples will be presented to illustrate techniques.

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 West 55th Street, Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

NEWS BRIEFS: news on current and Future Shock and Vibration activities and events

SAE TO HOLD VEHICLE NOISE AND VIBRATION CONFERENCE

The conference is scheduled for May 14-17, 1985, at the Grand Traverse Resort Village in Traverse City, Michigan. Technical sessions will cover measurement and test methods, noise and vibration characteristics, analysis methods, noise and vibration reduction, and the effects of noise on people.

A kick-off reception will be held Tuesday evening, May 14, and technical sessions begin Wednesday, May 15. An exposition is also being held in conjunction with the meeting.

Keynote addresses will be delivered at two luncheons. Dave Brown of the University of Cincinnati will talk on modal analysis at the Wednesday luncheon. On Thursday, Professor G.B.B. Chaplin of Essex University will discuss active noise control.

For further information contact: Laura Feix-Baker at SAE, 400 Commonwealth Drive, Warrendale, PA 15096 - (412) 776-4841.

REVIEWS OF MEETINGS

55th SHOCK AND VIBRATION SYMPOSIUM

23-25 October, 1984
Stouffer's Dayton Plaza Hotel
Dayton, Ohio

The 55th Shock and Vibration Symposium, sponsored by the Shock and Vibration Information Center (SVIC), was held in Dayton in October. It was hosted by the Aeronautical Systems Division of Wright-Patterson AFB. The formal technical program consisted of more than 60 papers (see Vol. 16, No. 9 of the **Digest** for the complete program; paper summaries are available from the SVIC; papers will be published in the **Shock and Vibration Bulletin**). The technical plenary sessions involved lectures by Dr. Alan Burkhard titled "CERT -- Where We Have Been - Where We Are Going" and Dr. Neville Rieger titled "Factors Affecting the Fatigue Life of Turbomachinery Blades and an Assessment of Their Accuracy." A large and interesting session on short discussion topics covering many areas of mechanical shock and vibration was again held. Dr. J. Gordan Showalter, Acting Director of SVIC, the members of the SVIC staff, and the program committee are to be congratulated for the assembly of an outstanding program on shock and vibration technology. Among the 350 participants were representatives of the federal government, industry, academic institutions, and foreign nationals. The combination of formal and informal technical programs effected a meaningful transfer of shock and vibration technology.

The Opening Session

Mr. Jerome Pearson of the Air Force Wright Aeronautical Laboratories, chairman of the opening session, introduced Mr. Keith Collier of Wright Aeronautical Laboratories who gave the welcome address. He discussed the relationship between the Wright brothers and Wright-Patterson Air Force Base and the four labs of the Base and their relationship to SVIC. He briefly discussed the technical challenges of a new series of aerospace projects.

The keynote address was given by Colonel Craig O. Schaum, Deputy for Engineering of Aeronautical Systems Division (ASD), Wright-Patterson Air Force Base, who discussed developments at ASD. Colonel Schaum traced the early developments in aeronautics noting the first instrument flight in 1932 and the first automatic landing instruments in 1937. He noted the ASD mission involving the F15, F16, and B1B development. Challenges to ASD and the shock and vibration community were given by General Stewart in 1974 -- high costs, pitfalls in technical specifications, and lack of integration in programs. Progress has been made in these directions. He discussed the avionics development program with respect to new technology, maintenance concepts, and system reliability. He noted that high tech, unreliable equipment cannot be tolerated. The emphasis on new equipment will be for operation in the field -- not the laboratory. Colonel Schaum closed with emphasis on less expensive test equipment yet increased reliability and maintainability.

The first of the three invited speakers was Dr. John C. Halpin of ASD who spoke on AVIP - Air Force Thrust for Reliability. Dr. Halpin discussed the implications of product assurance which is broader in nature than quality assurance. He discussed the independent nature of static strength and fatigue failure and how they affect the structural reliability. He noted that ASD was in the process of reexamination of their policies on failures including fracture mechanics. First the airframe was analyzed, then the engines, and now the avionics systems. At one time avionics was not taken as seriously as airframes, but the complexity of systems has made it impor-

tant. Avionics moved from mechanical to hydromechanical then to electromechanical. Dr. Halpin showed the classic relationships between number of failures and number of component parts, strength and flaws with time, stress cycles and failures, and flaw size and failures. The concept of use of stress screening to eliminate defects above a given flaw size was discussed. He discussed the predictability of electrical system failures on such components as printed circuit boards (PCB) along with traditional stress screening methods applied to these components. He noted the failure processes of PCB's including mechanical, chemical, and dielectric. He explained that not many failures were purely electrical.

Dr. Halpin discussed the concept of design to usage -- noting that the ability of the designer will depend on his knowledge of the component's function. Such things as inflight vibration, environmental conditions, ground maintenance, and shop induced vibration will affect life. An integrity program - acquisition approach was described. Principally the buying process and the interaction between the Air Force and the contractor were discussed. He noted the changing emphasis of reliability from classic reliability in the 1960's to physics of failure in the 1970's to physics of flaw failure in the present. Dr. Halpin summarized this talk with the concepts of extension of mechanical reliability to electrical reliability and called for elimination of redundancy caused by conservative design through better understanding of the physics of failure.

Dr. James J. Olsen of the Air Force Wright Aeronautical Laboratories gave the second invited paper on new dynamics programs in AFWAL Laboratories. Dr. Olsen discussed the structures and dynamics development program involving 220 scientists and engineers. The dynamics and structures test labs and typical tests were discussed. Dr. Olsen reviewed survivable structures, advanced aerostructural concepts, aircraft structural integration, space structures, and a technology base. The capabilities of the new test facility AGILE -- aircraft ground induced load environments -- were listed along with environments it is to simulate and what other tests such as those conceived by AGARD provide as an environment. He discussed landing gear design, flutter suppression, and damping of high sound pressure levels in the B1B. Dr. Olsen discussed the structural aspects, damping, and reliability of surveillance satellites. Passive versus active controls were discussed. He reviewed modeling and revision of NASTRAN for aeronautical and acoustical problems -- a new computer program called ASTROS. He showed some interesting curves on the acoustic control of turbulent boundary layers. Their photomechanics facility was briefly described along with the types of problems solved. In summary Dr. Olsen discussed opportunities for new technology and where we are going. New material technology including lower density aluminum, new fabrication processes, and stiffness of metal matrix composites. He briefly discussed some requirements for existing and future weapon systems.

The final invited paper was given by Mr. Robert N. Handcock, Manager of Environmental Engineering, Vought Missiles and Advanced Programs Division, on a decade of reliability testing progress. Mr. Handcock discussed progress in technical areas along with those things that prevent progress. He noted how, at the 45th Shock and Vibration Symposium, Mr. John Short and Col. Ben H. Swett had told horror stories on what was not being done. Design defects were found in the field long after equipment was produced. Col. Swett displayed measurements that showed how test environments were inadequate for proper simulation. Mr. Handcock reviewed the history of progress in reliability work including the introduction of stress screening, burn in tests, and product tests. He discussed the improvements in reliability and environmental tests such as design and environmental qualifications, test-analyze-fix, design proof tests, product screening, and product reliability and acceptance tests. Mr. Handcock discussed ongoing reliability projects including handbooks and guidelines, new reliability tests, and reliability test effectiveness. He closed with a discussion of challenges and opportunities including improved technical descriptions of environments, tailoring design and test

environments, improving facilities and procedures for life cycle tests, developing cost/benefit ratios for various tests, and revision of specifications and standards.

The Plenary Sessions

The first plenary speaker was Dr. Alan Burkhard of the Air Force Wright Aeronautical Laboratories who spoke on CERT -- Where We Have Been - Where We Are Going. Dr. Burkhard gave an extensive review of the CERT (Combined Environmental and Reliability Testing) program ending with challenges for the future.

Dr. Burkhard started with an overview of CERT -- why it developed, what it is, how it is applied in contracts, and what challenges arose. He noted that whenever funding cuts occur, CERT suffers. He questioned test effectiveness when defects were found but nothing was done about it. This fact led to the conclusion that something had to be done. In addition, tests had to simulate actual conditions. How to develop test credibility was discussed.

The CERT concept was conceived by *AFWAL in 1970. A CERT evaluation program* evaluated testing, performed technical and cost effectiveness studies, and developed a data base on CERT experience. Combined testing versus single environmental tests was explored. It was concluded that combined tests were needed. The CERT cost effectiveness on life cycle bases provided return on investment in 2-4 years. CERT is not a specific test profile -- it is a concept using engineering to develop the testing program. It involves tailoring test conditions -- application, test objectives, equipment design, and cost effectiveness. The test engineer must talk to the designer, manufacturer, and user.

Dr. Burkhard described the CERT test cycle including objectives, characteristics of missions, and nature of tests. He discussed environmental stresses -- measured from flight data, math modeling, engineering judgment based on experience, and table values in MIL STD 781C Appendix B. Analyses to determine test conditions, dynamic and thermal analyses, and electrical stress cycling analyses were discussed. The emphasis of CERT is on tailoring --one has to be an informed advocate to do an engineering study to provide test profile. This means a cost effectiveness versus benefit evaluation. Dr. Burkhard discussed the changing acquisition environment -- tailoring required, no sacred cows, and the right guides and data items. The benefits of CERT in the acquisition process were listed along with accelerated testing. He noted that data from ASD showed overall savings in their acquisition program and improved logistic supportability by reduced false removal rate and improved estimates of field reliability. CERT has gained effectiveness as it is applied.

Dr. Burkhard closed with some CERT challenges -- handbooks and guidelines should not be treated as gospel but rather should be living documents; test durations should be reduced while maintaining credibility of results; test and design activities should be better integrated; and a better understanding of environmental/failure causal relationships should be gained. Dr. Burkhard feels that CERT has reestablished test credibility and is a step toward improved *test and evaluation.*

The second plenary talk was given by Dr. Neville F. Rieger of Stress Technology, Inc. who spoke on factors affecting the fatigue life of turbomachinery blades and an assessment of their accuracy. Dr. Rieger gave an overview of blading types and the loads and factors that cause fatigue in blading. He discussed the types of blade stress measurements which have been made including laboratory and field work. The variation of blade damping with stress conditions was discussed along with damping mechanisms. Dr. Rieger revealed the modes of vibration of blades along with resonant and nonresonant vibratory response. From this response the blade vibratory stress is calculated. He reviewed the finite element models used to evaluate blade stresses and some examples of calculations performed. Finally, he discussed a variety of material properties and fatigue life of blading. Computational results were associated with tests to evaluate the accuracy of predictions made on assessments of blade life.

Technical Sessions

The technical sessions featured a varied number of papers on testing and computational techniques, instrumentation, and hardware. Sessions on dynamic testing, fluid-structure interaction, flight vehicle dynamics, damping and isolation, seismic loads, damping practices, machinery dynamics, system identification, and structural analysis were conducted. An interesting short discussion topics session was held on Thursday afternoon.

The session on dynamic testing featured papers on shaker systems, fatigue test systems, data analysis methods to support structural modeling, high velocity impact testing, and water impact testing. In the area of flight vehicle dynamics, papers involved airworthiness flight test programs, vibrations of air armament stores on fixed wing aircraft, whole store ground testing, design of test rigs with prescribed dynamic characteristics and spacecraft environments induced by ground transportation.

A number of papers were presented on fluid-structure interaction. This session included papers on panels subjected to shock loading, generalized dynamic analysis of interactive fluid-structural transient response, analysis of cavitation caused by shock wave interaction with a restrained mass, and models of offshore Lattice towers.

In the area of damping and isolation two sessions were held. The first session involved shock isolation of mobile shelters subject to blast overpressure, passive load control dampers, multiple transition polymetrics in shock and vibration damping, vibration and damping analysis of sandwich plates and panels. Papers given on damping practices included friction dampers, a different view of viscous damping, finite element analysis of damped blades to prevent flutter, temperature shift effects on complex modules, design of integrally damped spacecraft panels, and a different approach to designed in passive damping.

A session on seismic loads contained papers on the reliability of structures subject to multiple blast loads, shock environment in a civil defense blast shelter, earthquake induced motion environments in framed buildings, and development of test equipment and techniques.

Papers in the machinery dynamics session included gear dynamics analysis, coupled torsional-flexural vibration of a geared shaft system, design and testing of damped compressor vanes, modeling of lathe spindles, influence of axial torque on the dynamic behavior of rotors in bending, and sensitivity analysis of balancing planes using a dynamic condensation technique.

In the area of system identification an interesting session contained papers on structural damage detection, time domain modal analysis, multiple input excitation, time domain methods, and data acquisition/analysis/storage systems for structural dynamic testing using distributed processing architecture. Structural analysis papers included dynamic buckling of circular rings, effect of vibrations on humans, plate vibrations, dynamics of composites, and multilevel substructuring of large eigenproblems.

The Fifty-fifth Shock and Vibration Symposium was both technically informative and interesting yielding a large number of excellent papers. Again the plenary sessions with their overviews and philosophical insights added incomprehensible value to the meeting for new and experienced engineers. The Shock and Vibration Symposium continues to be the major annual event in this field and the SVIC can be congratulated for their continued maintenance of the quality of the technical presentations and the organization of interesting update lectures, overviews, and philosophical discussions so necessary for a complete meeting. Papers presented at the Symposium will be reviewed for quality of technical content and published in the **55th Shock and Vibration Bulletin** published by the SVIC.

R.L.E.

ABSTRACTS FROM THE CURRENT LITERATURE

ABSTRACT CONTENTS

AVAILABILITY OF PUBLICATIONS ABSTRACTED

None of the publications are available at SVIC or at the Vibration Institute, except those generated by either organization.

Periodical articles, society papers, and papers presented at conferences may be obtained at the Engineering Societies Library, 345 East 47th Street, New York, NY 10017; or Library of Congress, Washington, D.C., when not available in local or company libraries.

Government reports may be purchased from National Technical Information Service, Springfield, VA 22161. They are identified at the end of bibliographic citation by an NTIS order number with prefixes such as AD, N, NTIS, PB, DE, NUREG, DOE, and ERATL.

Ph.D. dissertations are identified by a DA order number and are available from University Microfilms International, Dissertation Copies, P.O. Box 1764, Ann Arbor, MI 48108.

U.S. patents and patent applications may be ordered by patent or patent application number from Commissioner of Patents, Washington, D.C. 20231.

Chinese publications, identified by a CSTA order number, are available in Chinese or English translation from International Information Service, Ltd., P.O. Box 24683, ABD Post Office, Hong Kong.

When ordering, the pertinent order number should always be included, not the **DIGEST** abstract number.

A List of Periodicals Scanned is published in issues, 1, 6, and 12.

MECHANICAL SYSTEMS

ROTATING MACHINES

85-193
Rotor Dynamic Analysis of a Nuclear Heat Transport Pump Under Normal and Part Void Conditions
P.E. Allaire, L.E. Barrett, R.D. Flack, F.W. Barton
Mechanical and Aerospace Engrg. Dept., Univ. of Virginia, Charlottesville, VA
Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 23-30, 9 figs, 5 tables, 19 refs

KEY WORDS: Rotors, Pumps, Nuclear power plants

A rotor dynamic analysis of a heat transport pump for nuclear power applications is conducted. Normal, part void and full void operating conditions are considered. The model includes the motor, coupling, pump, casing and external supports with the associated bearings. Predicted forces on the impeller are obtained from scaled test results for somewhat similar impellers. Vibration response due to synchronous impeller forces under normal operating conditions is calculated. Response due to nonsynchronous impeller forces for part or full void conditions is determined. The predicted results indicate low vibration levels for the design option of a separate full liquid supply to the hydrostatic pump bearing. This is true even with potential unusual system operating conditions which produce large impeller forces at nonsynchronous frequencies.

85-194
Transient Vibrations in Large Rotor-Bearing Systems
K. Krynicki, K. Marynowski
Inst. of Applied Mechanics, Technical Univ. of Lodz, Poland
Vibrations in Rotating Machinery. Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 39-43, 8 figs, 2 tables, 6 refs

KEY WORDS: Rotors, Pumps, Transient vibrations, *Finite element technique*, *Computer programs*

Computer simulation is applied to investigate the transient vibrational behavior of large rotor-bearing system. An automatic process of creation of mathematical model is based on the finite element method. The special method of computation of the transient impulse response in a large system is presented. Transient vibrations in 3-stage pumping rotor-bearing system are shown.

85-195
Even Multiple Vibrations of a Rotating Shaft Due to Secondary Moment of a Universal Joint
H. Ohta, M. Kato
Nagoya Univ., Japan
Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 199-204, 9 figs, 2 tables, 7 refs

KEY WORDS: Shafts, Lateral vibrations, Universal joints

The causes and characteristics of lateral vibrations occurring when a rotating shaft is driven by a universal joint are considered. A dynamical consideration is made in relation to the generation of secondary moment transmitted through the universal joint. The analytical results show that a driven shaft has a number of forced vibrations owing to secondary moment of the universal joint. Each of these vibrations excites a resonance when an angular velocity of the drive shaft coincides with one of the even integer submultiples of natural frequencies.

85-196

Dynamic Interactions Between Transmission and Foundation in the Case of Elastic Transmission Mountings (Dynamische Wechselwirkungen zwischen Getriebe und Fundament bei elastischer Getriebeaufstellung)

M. Weck, W. Rautenbach
Aachen, W. Germany

VDI-Z., 126 (13), pp 485-490 (1984), 10 figs, 8 refs (In German)

KEY WORDS: Shafts, Mountings, Structure-foundation interaction

Design criteria for elastic transmission mounting are the maximum allowable values for displacements on the driven and driving shafts. These displacements result from the restoring forces acting upon the mounting points. This contribution discusses the theoretical bases and the model concepts which allow description of the individual components. On the basis of measured impedance frequency responses, the developing foundation velocities for various mounting elements can be calculated beforehand.

85-197

Sub-rotational Speed Axial Vibrations of Shafts in Rotating Machinery

D. Dyer
Scientific Services Dept., Central Electricity Generating Board, South Eastern Region, Canal Road, Gravesend, Kent

Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 439-446, 8 figs, 9 refs

KEY WORDS: Shafts, Fans, Power plants, Vibration control

Sub-rotational speed axial vibrations have been observed on the shafts of large fans used in the boiler draft systems of power stations. This unusual behavior arises from the interaction between the axial vibration of a pedestal and the gravity force acting on the shaft which is slightly inclined to provide correct alignment at the coupling to the drive-motor. The factors controlling this motion are investigated using a simplified dynamic model and the benavior correlates well with that observed on the fans.

85-198

Partial Lateral Rotor to Stator Rubs

A. Muszynska
Bently Rotor Dynamics Res. Corp., Minden, NV

Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 327-335, 11 figs, 17 refs

KEY WORDS: Rotors, Rubs, Rotor-stator interaction

The paper gives a description of physical phenomena related to partial rotor rub against a nonrotating element. The phenomena include impacts which create a significant radial force, friction and modification of the system stiffness. Experimental results are documented and compared with the results of simple rotor model analysis. The rotor response shows the existence of steady state subharmonic vibrations of the order 1/2, 1/3, 1/4, . . . as a result of rotor transient free lateral vibrations following the impacts.

85-199

The Dynamics of Precession of a Supporting Centrifuge with the Cavity Partially Filled with a Viscous Fluid

U.A. Djoldasbekov, E.R. Rakhimov, A.Sh. Rakhmatullaev
Kazakh State Univ., Alma-Ata, USSR

Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 357-361, 3 figs, 3 refs

KEY WORDS: Rotors, Gyroscopes, Centrifugal forces, Fluid-filled containers

The dynamics of a support centrifuge partially filled with a viscous fluid is considered in this paper. The centrifuge is considered as a gyroscope, rotating with a sufficiently high angular velocity and performing a regular precession. Equations of motion for the viscous fluid in the cavity of the precessing centrifuge are derived.

85-200

A Digital System for Higher Harmonic Control of a Model Rotor

G. Lehmann
Deutsche Forschungs- und Versuchsanstalt f. Luft- und Raumfahrt E.V., Institut f. Flugmechanik Braunschweig, Fed. Rep. Germany

Vertica, 8 (2), pp 165-181 (1984), 18 figs, 7 refs

KEY WORDS: Rotors, Control equipment

For the four-bladed hingeless model rotor used at the DFVLR a computer based higher harmonic control system was developed. The description of the complete system is divided into the electrohydraulic servo actuator system, the static and dynamic balance system, and the digital quick-look and control system. The electrohydraulic assembly consists of three closed loop positioning systems working independently. Electrical inputs produce proportional piston strokes and feedback circuits perform a constant transfer function in the frequency range of interest.

85-201

Coupled Torsional-Flexural Vibration of a Shaft in a Geared System

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Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 67-72, 7 figs, 1 table, 3 refs

KEY WORDS: Flexible rotors, Shafts, Spur gears, Torsional vibrations

Coupled torsional-flexural vibration of a shaft in a spur geared system is investigated. The dynamic characteristics of systems where counter shafts are contained are discussed. Theoretically calculated natural frequencies and mode shapes are in good agreement with experimental values.

85-202

Non-Linear Dynamics of Flexible Rotor Systems

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Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 451-456, 7 figs, 15 refs

KEY WORDS: Flexible rotors, Bearings, Computer programs, Internal damping, External damping

In this paper the state-of-the-art is reported with respect to the development of a user friendly computer code in which various nonlinear influences are incorporated. Consecutively, several aspects are treated concerning the general modeling and the modeling of bearings and of material damping. Finally, the nonlinear dynamics of the integrated rotor-bearing system is discussed.

85-203

Optimum Vibration Control of Flexible Transmission Shafts

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Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 525-534, 12 figs, 19 refs

KEY WORDS: Flexible Rotors, Power transmission systems, Vibration control, Optimization

This paper discusses the intermediate shaft position force control of a flexible transmission shaft, operating over a speed range encompassing several critical speeds. By casting the equations of motion into the form of a linear programming problem it is shown how the optimum values of these control forces can be found. Identification procedures are developed which enable the parameters of chosen, passive control devices to be calculated. Comparisons are made between theoretical and experimental results for a transmission shaft with damping control. The application of the theoretical approach to the design and operation of an active electromagnetic control device is discussed.

85-204

Theory and Application of Magnetic Bearings with Integrated Displacement and Velocity Sensors

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Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 543-551, 13 figs, 8 refs

KEY WORDS: Rotors, Active vibration control, Magnetic bearings, Electromagnetic excitation

It is well known that rotor dynamics can be efficiently controlled by electromagnetic forces if sufficient measurement information is available. Solution is provided by combining the noncontacting displacement velocity-sensors and the bearing itself into one unit. The application in the area of actively controlling the vibrations of an asymmetric multibody rotor is demonstrated.

85-205

Modelling and Control of a Flexible Rotor with Magnetic Bearings

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Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 553-561, 7 figs, 1 table, 13 refs

KEY WORDS: Flexible rotors, Active vibration control, Electromagnetic properties

Electromagnetic bearings can support a flexible rotor without any contact and influence its vibrations simultaneously. For this active suspension and vibration control a direct-output-control design is presented. In practice the number of modes to be controlled most often exceeds the number of sensors and bearings, and for that case a modal design is derived. Two examples illustrate the control-design and the performance of the active bearings with numerical and experimental results.

85-206

Response Due to a Momentarily Created Unbalance

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Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 465-469, 2 figs, 10 refs

KEY WORDS: Rotors, Centrifuges, Unbalanced mass response, Whirling

When designing high-speed centrifugal separators it is essential to know the response due to a suddenly created unbalance. Time-history simulations of a complete rotor system by means of a digital computer are rather time-consuming. By considering only the synchronous response and the two most important eigenmodes at the operational speed, a rough-and-ready estimate of maximum deflexion is obtained.

85-207

Nonlinear Unbalance Response and Stability Thresholds of a Warped Multimass Rotor in Misaligned Bearings

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Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 499-506, 8 figs, 7 refs

KEY WORDS: Rotors, Bearings, Alignment, Unbalanced mass response

A second order perturbation method is presented to calculate nonlinear unbalance orbits of a multimass rotor supported by misaligned journal bearings. Ranges of high sensitivity of the stability thresholds with respect to bearing misalignment can be observed which may explain significant deviations between theoretical predictions and experimental data.

85-208

Mechanical Damping of Torsional Vibrations in Turbogenerators Due to Network Disturbances

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Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 139-144, 8 figs, 22 refs

KEY WORDS: Turbogenerators, Torsional vibrations, Viscous damping

The prediction of the behavior of turbogenerator systems during fault or disturbance conditions has become an important feature of system design and appraisal. The large shaft torsional oscillations that can develop, may lead to significant fatigue life expenditure. The damping of these oscillations consists of electrical and mechanical components. An approach is presented for evaluation of the variation due to shaft hysteretic damping. A simulation for a practical scheme shows that, in comparison with constant damping, the predicted oscillations decay to a low level more rapidly, but then persist for longer phenomenon observed in practice.

85-209

Large Unbalance Vibration in Steam Turbine-Generator Sets

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Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 491-497, 8 figs, 22 refs

KEY WORDS: Flexible rotors, Turbogenerators, Tilt pad bearings, Unbalanced mass response

Computations predict, for marginally stable systems, a potentially catastrophic nonlinear subharmonic jump-like phenomenon above a well defined unbalance magnitude. With tilting-pad journal bearings this does not occur. A greatly extended margin of safety is suggested for tilting-pad bearings.

85-210

Vibration Problems with Thermally Induced Distortions in Turbine-Generator Rotors

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Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 481-490, 14 figs, 4 refs

KEY WORDS: Rotors, Turbogenerators, Temperature effects

Thermally induced distortions in turbine generator rotors are briefly reviewed and qualitative explanations of their effects on the vibration behavior are given. Examples of different types of thermal problems are illustrated by reference to experience gained on plants operating in the SE Region of CEGB.

85-211

Variable Impedance Bearings for Turbogenerator Rotors

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Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 535-541, 8 figs, 7 refs

KEY WORDS: Rotors, Turbogenerators, Tuning, Hydrostatic bearings

Critical speeds of turbine generator rotors are determined by the mass and flexibility of the rotor itself and also by the dynamic characteristics of the rotor supports. Because of the difficulty in accurately predicting the support characteristics, the designer has a problem of ensuring that the normal running speed of a rotor is not close to a critical speed. In a combined theoretical and experimental study it has been shown that by mounting the rotor general bearing in a hydrostatic bearing, the overall rotor support characteristics can be tuned to enable rotor critical speeds to be moved. This tuning is carried out by adjusting the resistance offered by capillaries connecting accumulators to the hydrostatic bearing. Testing of a combined journal and hydrostatic bearing has confirmed the theory of its operation. A theoretical study for a full-size machine showed that its critical speed could be moved by over 350 rev/min and that its rotor vibration at running speed could be reduced by 80%.

85-212

Special Problems of Rotor Dynamics in the Design of Superconducting Generators with Multi-Shell Rotors

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Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 31-37, 12 figs, 1 table, 8 refs

KEY WORDS: Rotors, Turbogenerators, Flexural vibration, Torsional vibrations

Compared with turbine generators of conventional design, which already have very high power/weight ratios, superconducting generators offer big advantages in the way of the required capacity range and improved efficiency. The fundamental theoretical studies have been completed and the first test rotors are being proof-tested by a number of manufacturers. The completely different method of cooling the rotor at temperatures of only a few Kelvins demands effective thermal shielding. This is best achieved by using a construction consisting of a number of concentrically arranged hollow cylinders. An unconventional design of this nature gives rise to totally new problems regarding bending and torsional vibration. The flexural and torsional vibration behavior of a KWU superconducting 1000 MVA rotor is investigated in this paper.

85-213

The Influence of the Elastic Half-Space on Stability and Unbalance-Response of a Simple Rotor-Bearing Foundation System

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Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 1-12, 12 figs, 5 refs

KEY WORDS: Flexible rotors, Roller bearings, Fluid-film bearings, Rigid foundations, Unbalanced mass response

This system consists of an elastic shaft with a disc in roller or fluid film bearings. It is mounted on a rigid foundation block placed on the elastic isotropic half-space. The half-space degrees of freedom are eliminated with the aid of frequency dependent soil stiffness and damping coefficients. Numerical results of unbalance response and a stability analysis are presented for both systems.

85-214

Calculations of Long Rotors with Many Bearings on a Flexible Foundation

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Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 13-16, 3 figs, 2 tables, 8 refs

KEY WORDS: Multibearing rotors, Flexible foundations, Impedance matching technique

In calculating the rotor dynamic behavior of a rotor on a flexible foundation, it is often advantageous from a practical point-of-view to treat the rotor and the foundation as separate systems. The coupling is effected by impedance matching at the bearings. The non-conservative elements in the system are confined to the bearings. A calculation method is presented and a numerical example is given to illustrate the perplexity in interpreting the results.

85-215

A Linearized Stability Analysis of Rigid and Flexible Rotors in Plain Hybrid (Hydrostatic/Hydrodynamic) Journal Bearings

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Vibrations in Rotating Machinery, Proc. of 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 277-286, 12 figs, 14 refs

KEY WORDS: Rigid rotors, Flexible rotors, Journal bearings, Fluid-film bearings, Stability

The stability limits for a linearized model of a simple symmetric rotor (rigid/flexible) rotating in two similar plain line-entry (slot) hybrid journal bearings are presented. The bearing is represented by the eight linearized bearing dynamic coefficients. The values are obtained from a finite difference approximation of the Reynolds equation, with provision for source flow and fluid-film rupture. The fluid is assumed to be isoviscous. The onset of instability is predicted. A modified Bairstow's technique was used to obtain the roots of the characteristic equation, iteratively. The analysis shows that a wide range of stability limits may be possible, with bearings of the slot-entry configuration. It is shown that by careful selection of the bearing design parameters circular slot-entry bearings may compare favorably with those of non-circular hydrodynamic bearings.

85-216

Double-Frequency Forced Vibration of Turbine Blades Due to an Elliptical Orbit of the Rotor

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Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 373-381, 5 figs, 2 tables, 3 refs

KEY WORDS: Turbine blades, Steam turbines, Gas turbines, Forced vibration

The linear vibration behavior of the end blades (with unrestrained blade tips) in steam or gas turbines is investigated. The vibration results from an elliptical orbit of the rotor to which the blades are attached. By the use of greatly simplifying assumptions, an inhomogeneous Mathieu differential equation (parametric excitation) is obtained. The most significant practical point to note is that the blade vibration is forced at double the rotor frequency, hence there will be resonances at half of the critical blade rotational speed.

85-217

Calculated and Measured Natural Frequencies of Low Pressure Steam Turbine Blades and Wheels with Arch-Coverbands

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Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, York-

shire, Sept 11-13, 1984, pp 303-310, 10 figs, 1 table, 10 refs

KEY WORDS: Turbine blades, Rotors, Natural frequencies, Computer programs, Experimental data

Natural frequencies calculated by a finite element computer program are compared with experimental measurements for a low pressure turbine blade and for some last-stage LP steam turbine wheels with and without arch-coverbands. The calculated frequencies were within a few percent of the measured values for each of the structures analyzed, both at low and high rotational speeds. The program is based on the 20 noded isoparametric brick element. A new technique, called mixed integration, is used to eliminate spurious modes from the frequency range of interest.

85-218

Stability of an Eccentric Partially Filled Centrifuge

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Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 419-425, 5 figs, 15 refs

KEY WORDS: Rotors, Fluid-filled containers, Stability

The stability of a rotor with an eccentrically machined cylindrical cavity rotating with a constant angular velocity and partially filled with an inviscid incompressible fluid is analyzed. The rotor is symmetrically supported in the middle of a vertically mounted massless shaft with a linear restoring force. Emphasis was placed upon the effect of the eccentricity of the cavity in the rotor on the stability.

85-219

The Dynamics of a Flexible Bladed Disc on a Flexible Rotor in a Two-Rotor System

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General Electric Co., Cincinnati, OH 45215
Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 383-390, 8 figs, 10 refs

KEY WORDS: Flexible rotors, Bladed disks

This paper describes the development of the analysis of the transient dynamic response of a bladed disk on a flexible rotor. The rotating flexible bladed disk is considered as a module in a complete turbine engine structure. The analysis of the flexible bladed disk (FBD) module is developed for the non-equilibrated one-diameter axial mode.

85-220

The Influence of Unbalance on Cracked Rotors

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Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 193-198, 9 figs, 5 refs

KEY WORDS: Rotors, Cracked media, Unbalanced mass response, Finite element technique

The relationship between unbalance effects and crack behavior is investigated by means of a finite element mathematical model. The non-linear equations of motion are derived and numerically integrated. The method herein allows determination of the vibrations excited by crack. It determines what unbalance could be helpful in reducing the vibration levels of a cracked rotor passing through a critical speed.

85-221

Vibrational Behavior of a Rotor with a Cross-Sectional Crack

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Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 183-192, 9 figs, 2 tables, 8 refs

KEY WORDS: Rotors, Cracked media, Unbalanced mass response, Transient response, Stability

A method of calculating the vibrations of a rotor with a cross-sectional crack of the opening and closing type is presented. The modeling of the crack is described. The method enables the calculation of unbalance response, transient vibration and the control of stability for a rotor with an arbitrary number of degrees of freedom. Some results are presented for a Laval-shaft and explained by the perturbation method.

85-222
Aeroelasticity in Turbomachine-Cascades
A. Boelcs, T. Fransson, P. Suter
Ecole Polytechnique Federale de Lausanne, Switzerland
Rept. No. EPFL/LTA-TM-3-84, 25 pp (Feb 1, 1984) AD-A141 905

KEY WORDS: Flutter, Prediction techniques, Rotor blades (turbomachinery)

An aeroelastician needs reliable efficient methods for calculation of unsteady blade forces in turbomachines. The validity of such theoretical (or empirical) prediction models can only be established if researchers apply their flutter and forced vibration predictions to a number of well documented experimental test cases. Under the present project, a report with nine selected standard configurations for the mutual validity of experimental and theoretical results has been prepared and distributed.

85-223
Turbulence Modeling for Three-Dimensional Shear Flows over Curved Rotating Bodies
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AIAA J., 22 (10), pp 1420-1428 (Oct 1984), 11 figs, 22 refs

KEY WORDS: Turbulence, Rotating structures, Turbomachinery

It is known that curvature and rotation affect a turbulence structure substantially, and a knowledge of these effects is essential for the improved prediction of flow over rotating bodies. A turbulence model which includes the effects of curvature as well as rotation has been developed. Different hypotheses are introduced to model the higher order unknowns in the Reynolds stress, the turbulent kinetic energy and dissipation rate equations are discussed. A detailed analysis of the effect of the rotation on each component of the Reynolds stress tensor is presented for hypothetical cases such as the pure shear flow in a rotating frame. Calculations show that the effects of rotation on turbulent shear stresses are more pronounced in a centrifugal type of turbomachinery than an axial type.

85-224
Stability Analysis of Rotor-Bearing System Subjected to Cross-Coupling Force
M. Kurohashi, T. Fujikawa, R. Kawai, T. Iwatsubo
Kobe Steel Limited, Kobe, Japan
Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 51-58, 11 figs, 7 refs

KEY WORDS: Rotors, Stability, Fluid-induced excitation

An approximate method for calculating the logarithmic decrement and the limit cross-coupling of a rotor system supported by journal bearings and subjected to a fluid cross-coupling force is induced. The approximate expressions show a good agreement with the precise numerical solutions. The stability of the rotor-bearing system is investigated experimentally.

85-225

Stability and Control of Parameter Excited Rotor Systems (Stabilitatsverhalten und Regelung parametererregter Rotorsysteme)

E. Anton

Fortschritt-Berichte VDI-Zt., Reihe 8, No. 67 (1984), 140 pp, 43 figs, 8 tables. Summarized in VDI-Z, 126 (12), p 463 (June 1984). Avail: VDI-Verlag GmbH, Postfach 1139, 4000 Dusseldorf 1, Germany. Price: 86 DM (In German)

KEY WORDS: Rotors, Stability

The vibration of rotor-bearing systems, such as centrifuges, caused by design asymmetries of components at operating speeds can be improved by installing active magnetic bearings into control circuits. The aim of this investigation was to provide a systematic procedure for the design of control for such systems. Approximation formulas to investigate the behavior of controlled as well as uncontrolled systems were developed.

85-226

Natural Frequencies of Shell-Centrifuges

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Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 45-50, 3 figs, 1 table, 12 refs

KEY WORDS: Rotors, Shells, Hole-containing media, Natural frequencies, Finite element technique

A procedure for automatic determination of the natural vibration frequencies of thin-walled rotor-shells with uniformly space holes is presented. An approximate method based on the definition of an equivalent inertial moment is proposed.

85-227

Some Recent Advances in Rotor Dynamics

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Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp xi-xx, 6 figs, 2 tables, 59 refs

KEY WORDS: Rotors, Reviews

This critical review of the recent literature on the art and science of rotor dynamics identifies some significant advances in the field. Computation and measurement of the dynamic characteristics of rotors, bearings, seals, squeeze-film dampers, and foundations are discussed. The present and future roles of microprocessors are examined. Areas of research that would increase the usefulness of rotor-dynamic technology are suggested.

85-228

The Coupled Lateral Torsional Vibration of a Geared Rotor System

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Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 59-66, 8 figs, 2 tables, 9 refs

KEY WORDS: Rotors, Gears, Lateral vibrations, Geometric imperfection effects

This study deals with the coupled lateral and torsional vibration of geared rotors. The effect of periodic variation of meshing teeth stiffness is considered. On the assumption that the form of the variation of meshing teeth stiffness is rectangular, the stability condition is analyzed. Forced vibration caused by a tooth profile correction is evaluated by the periodic solution whose period is a mesh period.

85-229

Multiple Pure Tone Generation in Aeroengine Fans at Subsonic and Supersonic Relative Tip Speeds

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AIAA J., 22 (10), pp 1366-1374 (Oct 1984), 6 figs, 1 table, 27 refs

KEY WORDS: Fans, Noise generation

It has been generally assumed that the multiple pure tones (MPT's) exist only at supersonic relative tip speeds. However, recent narrowband analysis of fan noise at subsonic relative rotor tip speeds has shown that what was previously assumed to be a purely broadband noise, is, in fact, a broadband noise mixed with MPT's. Previous theories, based on shock wave propagation, need to be extended to explain this and other related phenomena. In this paper, the limitations of the linear acoustic equations are reviewed. These limitations make it essential to use a nonlinear model for the MPT generation problem. It is shown that there are three different MPT generation mechanisms. An example of an application of the theory to the analysis of narrowband data is provided.

85-230
A Study on Oil Whip for a Shaft Supported by Multiple-Bearings
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Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 17-21, 13 figs, 4 refs

KEY WORDS: Rotors, Oil whip phenomena

This paper describes an analytical technique to calculate the oil whip instability threshold speed for multi-span rotor bearing systems. The calculation method is based on the transfer matrix approach and uses complex variable notation to develop the overall system matrix. An experiment on rotors supported by three bearings was carried out successfully to prove the effectiveness of the theory.

85-231
Non-linear Vibrations of a Textile Machine Rotor
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Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 447-450, 4 figs, 4 refs

KEY WORDS: Rotors, Disks, Variable mass

In the paper the free vibrations of a textile machine rotor are considered. The rotor contains a weightless shaft and a disc with variable mass. The force in the shaft is assumed to be nonlinear. Mass of the disc is varying due to the winding up of the textile band by constant angular velocity. Severe vibrations occur due to the mass varying. When the nonlinearity is small and the variation of mass is a function of "slow time" the vibrations can be denoted not only numerically but also analytically by use of the multiple scales method. The results are compared.

85-232
The Vibratory Airloading of Helicopter Rotors
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Vertica, 8 (2), pp 73-92 (1984), 15 figs, 3 tables, 13 refs

KEY WORDS: Rotors, Helicopters, Vibration excitation

A survey has been made of all major wind tunnel and full-scale flight tests conducted over the last 29 years to examine the nature of the vibratory aerodynamic loading which causes helicopter vibration. Using computer generated surface plots, the paper compares the airload distributions for rotors which have from 2 to 6 blades by presenting the data in identical plotting formats which allow comparisons of the effects of major parameters. Blade number, blade/vortex proximities, propulsive force and forward speed are considered.

RECIPROCATING MACHINES

85-233
Rotor Dynamics of Reciprocating Compressors
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The Ship Res. Inst. of Norway, Marine Technology Ctr., Trondheim, Norway
Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 457-464, 14 figs, 4 refs

KEY WORDS: Rotors, Reciprocating compressors, Simulation, Dynamic response, Monitoring techniques

The paper describes the simulation of the dynamic response of the rotor system in a reciprocating air compressor due to varying operating conditions and load. Selected results gathered from laboratory test and field measurements will be evaluated and compared with the simulated response.

METAL WORKING AND FORMING

85-234
Chatter Coupled Vibrations of a Large Vertical Lathe, Rotating Table and Its Tool Slide
Z.A. Parszewski, T.J. Chalko
The Univ. of Melbourne, Australia
Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 349-356, 7 figs, 5 refs

KEY WORDS: Lathes, Chatter, Self-excited vibrations, Case histories

This paper presents an analysis and case history of chatter caused vibrations of a large vertical lathe. Very heavy vibrations were observed to occur at some extensions of the overhead vertical slide during the machining of helical grooves in large cable drums. A generalized 3-degree of freedom model of the lathe comprising two mechanical subsystems was developed. Differential equations of motion for model elements were solved by numerical integration with the aid of a digital computer for various slide extensions and values of the tangential component of the cutting force. Critical extension lengths of the overhead slide were recognized as corresponding to the convergence of the two natural frequencies in the tool supporting structure. This led to large vibrations in the system coupled by the tangential component of the cutting force supplied by the turntable drive as an energy source. The influence of this force variation was also analyzed and a limit value corresponding to the stability threshold was determined.

STRUCTURAL SYSTEMS

FOUNDATIONS

85-235
Pile Response to Seismic Waves
A.F. Barghouthi
Ph.D. Thesis, The Univ. of Wisconsin-Madison, 183 pp (1984), DA8405410

KEY WORDS: Pile structures, Seismic response

This study deals with the response of a single pile to seismic waves. The response of the pile foundation to incident shear, compression and Rayleigh waves is investigated. A closed form solution is obtained for Rayleigh wave free field soil displacements in a two-layer viscoelastic soil system by solving Haskell's period equation numerically. The soil displacements obtained from the Rayleigh wave solution are compared with those produced by shear and compression waves.

85-236
Earthquake Induced Pore Pressures in the Foundation of a Sea Dyke
A.N. Schofield, K. Venter
Dept. of Engrg., Cambridge Univ., UK
Rept. No. CUED/D-SOILS/TR-150, 21 pp (1984), PB84-205541

KEY WORDS: Foundations, Dykes, Earthquake response

This paper is concerned with one of a series of models of the sand foundation of a long length of sea coast dykes. The purpose of the model test was to study the generation and dissipation of excess pore water pressures in the sand and the nature and extent of damage to the dyke during and after earthquake shaking.

85-237
Changes in Shear Modulus and Damping in Cohesionless Soils Due to Repeated Loading
R.P. Ray
Ph.D. Thesis, The Univ. of Michigan, 433 pp (1984), DA8412232

KEY WORDS: Soils, Cyclic loading, Stiffness coefficients, Damping coefficients

This study focused on the influence of number of cycles of loading on the stiffness and damping of sand and silt. Five soils were tested in this study: three sands with different gradations and two silts. The soils were tested using a hollow cylinder torsional shear device which was controlled by microcomputer. Because the microcomputer allowed a variety of loading options, the soils were tested under stress-controlled, or strain-controlled conditions with uniform or irregular loading histories.

UNDERGROUND STRUCTURES

85-238
Examination of the Final Design of the Rotor Blades GROWIAN 1
R. Lehmhus
Germanischer Lloyd, Hamburg, Fed. Rep. Germany
Rept. No. BMFT-FB-T-83-306, ISSN-340-7608, 61 pp (Dec 1963), N84-25174 (In German)

KEY WORDS: Rotor blades (turbomachinery), Power plants, Wind forces

The design analysis of rotor blades for the wind energy converting system GROWIAN 1 is described. Technical safety supervision of the rotor blade construction included an examination of stress and vibration calculations and of design and production data. Materials testing was also completed. The results obtained from experimental studies of components and type tests of materials were taken into account in the overall assessment of the rotor blade design.

HARBORS AND DAMS

85-239
Hydrodynamic Pressure on Short-Length Gravity Dams
A.A. Rashed, W.D. Iwan
The Johns Hopkins Univ., Baltimore, MD 21218
ASCE J. Engrg. Mech., 110 (9), pp 1264-1283 (Sept 1984), 10 figs, 7 refs

KEY WORDS: Dams, Hydrodynamic excitation

Analytical expressions are derived for the hydrodynamic pressures generated in reservoirs behind short-length gravity dams, and resulting from vibrational motions of the dam and ground motions. The dams have vertical upstream faces.

85-240
Dynamic Response Behavior of Xiang Hong Dian Dam
R.W. Clough, K.T. Chang, H.Q. Chen, R.M. Stephen

California Univ., Richmond, CA
Rept. No. UCB/EERC-84/02, NSF-CEE-84017, 171 pp (Apr 1984), PB84-209402

KEY WORDS: Dams, Mathematical models, Vibration response

The purpose of this study was to evaluate and improve the mathematical models used to represent the foundation rock and the reservoir. Measurements were made of the vibration behavior of Xiang Hong Dian Dam. Vibrations were excited by rotating mass shakers nd also by ambient vibration effects in the environment; measured vibration mode shapes. Frequencies were compared with a finite element model analysis of the dam, reservoir, and foundation rock.

ROADS AND TRACKS

85-241
Resilient Properties of Unbound Roadbase Under Repeated Triaxial Loading
H.C. Mayhew
Transport and Road Res. Lab., Crowthorne, UK
Rept. No. TRRL/LR-1088, 33 pp (1983), PB84-204130

KEY WORDS: Pavements, Roads, Dynamic tests

A study of the non-linear elastic behavior of unbound, granite and limestone road-base material was made. Values of moduli and Poisson's Ratio determined to provide data for modeling the response of traffic loaded pavements are reported. A dynamic triaxial testing machine incorporating interactive computer control was designed.

POWER PLANTS

85-242
Two Dimensional Vertical Model Seismic Test and Analysis for HTGR Core
T. Ikushima, T. Honma
Japan Atomic Energy Res. Inst., Tokyo, Japan
Rept. No. JAERI-1282, 75 pp (Feb 1983), DE84700830 (In Japanese)

KEY WORDS: Seismic tests, Nuclear reactors, Experimental data

The resistance against earthquakes of high-temperature gas cooled reactor (HTGR) core with block-type fuels is not fully ascertained yet. Seismic studies must be made if such a reactor plant is to be installed in areas with frequent earthquakes. In the paper the test results of seismic behavior of a half-scale two-dimensional vertical slice core model and analysis are presented.

OFF-SHORE STRUCTURES

85-243
On Reliability and Active Control of Tension Leg Platforms
Z. Prucz
Ph.D. Thesis, State Univ. of New York at Buffalo, 116 pp (1984), DA8410585

KEY WORDS: Off-shore structures, Drilling platforms, Active control

This dissertation is concerned with safety and structural integrity of offshore Tension Leg Platforms subject to extreme environmental loadings. A reliability model is presented and the technique of active control is considered as one of the possible means for ensuring structural safety during severe loading episodes.

85-244
Random Dynamic Analysis of Multi-Body Offshore Structures
R.S. Langley
Cranfield Inst. of Technology, Cranfield, Bedford MK40 OAL, UK
Ocean Engrg., 11 (4), pp 381-401 (1984), 14 figs, 23 refs

KEY WORDS: Off-shore structures, Wave forces, Random response

A general method for the dynamic analysis of multi-body offshore structures is presented. It is based on a constraint matrix approach. A method of deriving the constraint matrix for a general structure is given, and this is then used to derive the equations of motion of a whole system from those of it's component parts. The response of the system to both first and second order random wave forces is found and then used to calculate the forces and moments in the connecting mechanisms.

VEHICLE SYSTEMS

GROUND VEHICLES

85-245

Noise Emission of Road Vehicles: Reconstitution of the Acoustic Signature

B.M. Favre, B.T. Gras
Institut de Recherche des Transports, Centre d'evaluation et de Recherche des Nuisances et de l'Energie, 109, avenue Salvador Allende, 69500 Bron, France
J. Sound Vib., 93 (2), pp 273-288 (Mar 22, 1984), 12 figs, 3 tables, 9 refs

KEY WORDS: Ground vehicles, Noise generation, Acoustic signatures

The paper describes a model that can be used to reconstitute the acoustic signature (sound pressure level) of a moving road vehicle. Account is taken of the Doppler and ground effects and of the directional characteristics of the noise emitted by the vehicle. The variations of the usual noise indices (maximum noise level, equivalent noise level due to the passing by of the vehicle) with different paraeters concerned, are considered and such variations compared with experimental results. It is shown, on the basis of the assumptions made, how a monopole source provides a good representation of a road vehicle.

85-246

Brake Squeal Problem in Underground Trains

R.S. Rao, N.F. Rieger
Indian Inst. of Technology, New Delhi, India
Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 337-347, 15 figs, 1 table, 14 refs

KEY WORDS: Brakes (motion arresters), Subway railways, Subway cars

This paper describes a workable mathematical model of an underground train disk-braking system, to predict the conditions under which it can squeal. Tests conducted on an underground train to detect the squeal are described. It is shown that the proposed mathematical model can predict whether squeal occurs.

85-247

Wheelset Mechanics During Wheelclimb Derailment

A. Karmel, L.M. Sweet
General Motors Res. Labs., Warren, MI 48090
J. Appl. Mech., Trans. ASME, 51 (3), pp 680-686 (Sept 1984), 7 figs, 20 refs

KEY WORDS: Wheelsets, Railroad cars, Derailment

An analysis of the mechanics and dynamics of a railroad vehicle wheelset during flange contact and wheelclimb derailment is presented. The theoretical model includes wheelset lateral, vertical, roll, yaw, and axle rotation degrees of freedom. Lateral displacement of the truck frame is included. Computational methods for simulation of the nonlinear dynamic model are discussed. Results of the simulation demonstrate the significance of the various degrees of freedom on wheelset motion and on predicted values of the derailment quotient.

SHIPS

85-248
Cost Effectiveness of Noise Abatement Techniques for Small Vessels: Final Report
B. Dibner, A.W. George, I.B. Jacobson, W.A. Mayberry
Offshore Marine Service Assn., New Orleans, LA
Final Report No. MA-RD-770-84002A, 165 pp (Dec 1983), PB84-205905; Executive Summary Rept. No. MA-RD-84002B, 41 pp (Dec 1983), PB84-206499

KEY WORDS: Boats, Noise reduction

This report describes cost-effective means to reduce noise aboard small vessels. Standardized noise measurements were made on supply boats, utility boats, anchor-handling boats, crewboats, tugboats and towboats of various sizes and designs. Noise sources and transmission paths were identified and noise reduction measures for existing vessels and new buildings were designed using engineering design, construction techniques, and administrative controls. Costs for noise reduction treatments for new and retrofit vessels were calculated by estimators from shipyards participating in the study. The results show the cost-effectiveness of alternative treatments by comparing treatment costs to estimated noise reductions, measured in dB(A). The report recommends different sound reduction treatments for each type of vessel. These treatments are applied in engine rooms, adjacent spaces, and remote spaces. Recommendations are made for both retrofits and new buildings.

AIRCRAFT

85-249
Analysis of a Semi-Levered Suspension Landing Gear with Some Parametric Study
P.J. Reddy, V.T. Nagaraj, V. Ramamurti
Helicopter Design Bureau, Hindustan Aeronautics Ltd., Bangalore, India
J. Dynam. Syst., Meas. Control, Trans. ASME, 106 (3), pp 218-224 (Sept 1984), 11 figs, 35 refs

KEY WORDS: Landing gear, Vehicle suspension systems, Helicopters

A set of nonlinear differential equations describing the response of a semilevered suspension type of landing gear with a single stage oleo-pneumatic shock strut is derived. This includes the kinematics of the articulation of the gear, oil compressibility effect, wheel spin-up as a function of slip ratio, and the hydraulic, pneumtic, and friction forces of the shock strut. A parametric study on a gear of a helicopter has been conducted.

MISSILES AND SPACECRAFT

85-250
Active Suppression of Aeroelastic Instabilities for Forward Swept Wings
T.E. Noll, F.E. Eastep, R.A. Calico
Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH
Rept. No. AFWAL-TR-84-3002, 170 pp (Dec 1983), AD-A141 739

KEY WORDS: Aircraft wings, Wing stores, Active flutter control

Analytical studies are conducted to investigate the potential of using active feedback control systems for preventing multiple aeroelastic instabilities from occurring. With the addition of wing mounted external stores, the classical bending/torsion flutter instability is driven to lower airspeeds into the vicinity of the aeroelastic instabilities.

85-251
Development of Baseline Random Vibration Environment Criteria for Shuttle Pallet Payload Subsystems
F.J. On

NASA Goddard Space Flight Ctr., Greenbelt, MD
Rept. No. NASA-TM-86087, 126 pp (Apr 1984), N84-23666

KEY WORDS: Space shuttles, Random vibration

This paper presents a statistical evaluation of measured random vibration response data obtained from the Office of Space Science-1 (OSS-1) pallet payload. The data were measured during the acoustic test simulation (September 1980) and the ascent phase of the flight of STS-3, Orbiter 102 (launched from the Kennedy Space Center on March 22, 1982). Acoustic test efficiency factors are evaluated based on the Dynamic, Acoustic and Thermal Environments (DATE) instrumentation as the source of the measured vibration data.

85-252
Decentralized Active Control System for a Large Flexible Structure in Space
A. Danesi
Rome Univ., Rome, Italy
15 pp (Jan 1984)(Conf. Proc. on Guidance and Control Techniques for Advanced Space Vehicles (37th), Florence, Italy, Sept 27-30, 1983, AD-P003 397

KEY WORDS: Space structures, Active vibration control, Mode shapes

A new strategy in controlling the modal shapes of large structure in space is presented in this study. An active low authority modal control system is provided to measure and control the local structural deformations to obtain modal shapes resulting in acceptable pointing error for the RF radiators.

BIOLOGICAL SYSTEMS

HUMAN

85-253
Noise Levels and Hearing Thresholds in the Drop Forging Industry
W. Taylor, B. Lempert, P. Pelmear, I. Hemstock
Univ. of Dundee Medical School, Dundee, Scotland
J. Acoust. Soc. Amer., 76 (3), pp 807-819 (Sept 1984), 11 figs, 15 tables, 10 refs

KEY WORDS: Forging machinery, Noise generation, Human response

A-weighted equivalent continuous noise levels for hammer and press operations in a drop-forging industry were determined using both tape recordings of the noise and personal noise dosimeters. For long-term exposures of 10 years or more, the results of this study indicate that hearing losses resulting from impact noise in the drop-forging industry are as great or greater than those resulting from continuous noise.

85-254
Inquiry on Noise Causing Complaints in Residential Areas near Chemical Plants
M. Haberle, D. Dovener, D. Schmid
BASF AG, Carl-Bosch-Strasse 38, D-6700 Ludwigshafen' Rhein (Fed. Rep. of Germany)
Appl. Acoust., 17 (5), pp 329-344 (1984), 6 figs, 9 tables, 7 refs

KEY WORDS: Industrial noise, Human response

Fifty complaints out of the 230 were quantitatively evaluated with respect to the background and noise level at the location of complaint. It resulted, that only 16% of the complaints are based on broadband noise, whereas 84% on impulse noise and single tones. Broadband noise causes

complaints beginning at 65 dB(A), impulse noise at 56 dB(A) and single tones at 50 dB(A).

85-255
Community Reaction to Impulsive Noise: A 10-Year Research Summary
P.D. Schomer, R.D. Neathammer
Construction Engrg. Res. Lab. (Army), Champaign, IL
Rept. No. CERL-TR-N-167, 209 pp (Feb 1984), AD-A141 762

KEY WORDS: Impact noise, Ammunition, Human response

A major concern of Army planners is the trend toward siting off-installation housing and other noise-sensitive land uses in areas exposed to high noise levels produced by Army training or operational activities. To do effective noise-related assessments and planning the Army must be able to assess the community reaction to impulse noise. The altitudinal surveys provide most of the data in this report.

MECHANICAL COMPONENTS

ABSORBERS AND ISOLATORS

85-256
Flexural Support Member Having a High Ratio of Lateral-to-Axial Stiffness
W.M.B. Haas
Dept. of Energy, Washington, D.C.
PAT-APPL-6-507 189, 13 pp (June 1983)

KEY WORDS: Supports, Instrumentation mounts, Equipment mounts

A convoluted flexible support structure is provided which is capable of supplying a lateral to axial spring rate in excess of 1000 to 1. A support member in the form of a steel disc having a specified number of rather large radius, concentric convolutions is described. It has a thickness in the range of from about 0.01 to 0.02 inch an axial stiffness of about 50 pounds/inch while the lateral stiffness is about 100,000 pounds/inch. The support member may be used to support a vibration device where the lateral motion of the vibrator must be highly restricted while providing relatively free axial displacement of about +-.25 inch.

85-257
Shock Wave Absorber Having Apertured Plate
Y.W. Shin, A.H. Wiedermann, C.E. Ockert
Dept. of Energy, Washington, D.C.
PAT-APPL-6-526 765, 22 pp (Aug 1983)

KEY WORDS: Shock absorbers, Energy absorption, Pipes, Fluid-filled containers

The shock or energy absorber disclosed herein utilizes an apertured plate maintained under the normal level of liquid flowing in a piping system. The degree of openness (or porosity) of the plate is between 0.01 and 0.60. The energy level of a shock wave travelling down the piping system thus is dissipated by some of the liquid being jetted through the apertured plate toward the cavity. The cavity is large compared to the quantity of liquid jetted through the apertured plate, so there is little change in its volume. The porosity of the apertured plate influences the percentage of energy absorbed.

85-258
Shock Wave Absorber Having a Deformable Liner
C.K. Youngdahl, A.H. Wiedermann, Y.W. Shin, C.A. Kot
Dept. of Energy, Washington, D.C.
PAT-APPL-6-526 767, 18 pp (Aug 1983)

KEY WORDS: Shock absorbers, Pipes, Fluid-filled containers, Linings

This invention discloses a shock wave absorber for a piping system carrying liquid. The absorber has a plastically deformable liner defining the normal flow boundary for an axial segment of the piping system. A nondeformable housing is spaced outwardly from the liner so as to define a gas-tight space there between.

85-259
Parametric Studies on the Load-Deflection Characteristics of Hydraulic Snubbers
M. Subudhi, J. Bezler, P. Curreri, M. Hartzman
Brookhaven National Lab., Upton, NY
Rept. No. BNL-NUREG-34546, CONF-840647-13, 13 pp (1984)(Pres. at ASME Pressure Vessel and Piping Conf., San Antonio, TX, USA, June 17, 1984)

KEY WORDS: Snubbers, Piping systems, Nuclear power plants, Computer programs, Parametric response

Hydraulic snubbers are extensively used in the nuclear power industry for supporting high energy piping systems subjected to dynamic loadings. These devices allow the piping system to displace freely under slowly applied loads, but lock up under sudden excitations. This paper presents the governing differential equations describing the hydro-mechanical mechanisms of a typical snubber. A finite difference computer code, SNUBER, was developed to solve these equations.

85-260
Combined Analysis and Testing for Qualification of Seismically Supported Control Element Drive Mechanisms of a PWR
K.H. Haslinger, C.W. Ruoss
Combustion Engrg. Inc., Windsor, CT
ASME Paper No. 84-PVP-87

KEY WORDS: Snubbers, Nuclear reactors, Seismic analysis, Seismic tests

The adequacy of a newly developed seismic support for control element drive mechanisms located in high seismic environments was demonstrated by a large combined test and analysis program. The seismic snubber system enabled shifting of component frequencies away from high response spectra peaks and also helped to reduce deflections.

85-261
New Suspension Bearing Unit for Cars
B. Veglia, M. Debenedetti
RIV-SKF Turin
Ball Bearing J., 220, pp 20-25 (July 1984), 8 figs

KEY WORDS: Suspension systems (vehicles)

Most modern cars utilize McPherson-type front wheel suspension incorporating shock absorber and helical spring. The use of a rolling bearing at the tope of the strut enables the spring to turn freely during steering so that torsion in the spring is eliminated. Vibrations from the wheels are damped by rubber components. The new McPherson Strut Bearing Unit developed by SKF integrates bearing and damping function. These bearing units give the advantages of simpler mounting, mass savings, lower costs and added comfort.

85-262
Effects of Mode Interaction on Collapse of Short, Imperfect, Thin-Walled Columns
D. Hui
Ohio State Univ., Columbus, OH 43210
J. Appl. Mech., Trans. ASME, 51 (3), pp 566-573 (Sept 1984), 6 figs, 20 refs

KEY WORDS: Columns, Buckling, Energy absorption, Initial deformation effects

The present paper deals with the design of beneficial geometric imperfections of short, thin-walled columns in order to maximize their energy absorption. The investigation showed that under axial compressive load, the symmetric mode has a much higher energy absorption than the antisymmetric mode as measured by the

area under the curve of applied load versus end-shortening curve. Thus, an attempt is made to introduce imperfections in the beneficial symmetric mode so that the mode shapes of extremely large deflection in plastic collapse will also be of the symmetric type. The two-mode stability problem is studied using Koiter's theory of elastic stability.

85-263
Vibration Isolation for Broadband Gravitational Wave Antennas
P.R. Saulson
Massachusetts Inst. of Technology, Cambridge, MA 02139
Rev. Scientific Instrum., 55 (8), pp 1315-1320 (Aug 1984), 8 figs, 5 refs

KEY WORDS: Active vibration control

An active vibration isolation system which is a prototype of an isolation system for an interferometric gravitational wave antenna is discussed. Particular attention is paid to factors which limit the isolation which can be achieved. The effective resonant frequency of the test mass was reduced to 0.04 Hz. Between 3 and 8 Hz, this was sufficient to bring the motion of the test mass within a factor of 2 of its Brownian motion amplitude.

85-264
Impact Resistance of Fiber Composites: Energy Absorbing Mechanisms and Environmental Effects
C.C. Chamis
NASA Lewis Res. Ctr., Cleveland, OH
Rept. No. E-1996, NASA-TM-83594, 25 pp (1983), N84-24712

KEY WORDS: Energy absorption, Composite beams, Fiber composites

Energy absorbing mechanisms were identified by several approaches. The energy absorbing mechanisms considered are those in unidirectional composite beams subjected to impact. The approaches used include: mechanic models, statistical models, transient finite element analysis, and simple beam theory. Predicted results are correlated with experimental data from Charpy impact tests.

85-265
State-Variable Feedback Control of Rotor-Bearing Suspension Systems
R. Stanway, J. O'Reilly
Dept. of Mech. Engrg., Univ. of Liverpool, UK
Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 515-524, 6 figs, 2 tables, 20 refs

KEY WORDS: Suspension systems (vehicles), Rotating machinery, Vibration control

This paper describes a procedure for eigenstructure assignment with application to vibration control of suspension systems for rotating machinery. The use of the technique is illustrated by a numerical study.

SPRINGS

85-266
A Two-Dimensional Shear Spring Element
A.S. Kuo
Fairchild Republic Co., Farmingdale, NY
AIAA J., 22 (10), pp 1460-1464 (Oct 1984), 13 figs, 5 refs

KEY WORDS: Spring constants, Adhesives, Joints

A new, two-dimensional continuous shear spring element was developed to calculate the stress intensity factors in adhesively bonded structures. The quadratic quadrilaterl isoparametric element was adopted to explain the formulation of element stiffness. In contrast to the conventional discrete shear spring element, the new element takes into account the continuous

nature of load transfer between cracked and uncracked adherends. The capability of the new element was validated with experimental data from four types of adhesively bonded specimens. The new element is also applicable to modeling the core of honeycomb sandwich structures.

BLADES

85-267

The Equations of Motion of n-Bladed Propellers with Arbitrarily Positioned Hinges and Their Application to an Experimental One-Bladed Wind Turbine

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Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 363-372, 8 figs, 9 refs

KEY WORDS: Turbine blades, Wind turbines

The equations of motion of n-bladed propellers with arbitrarily positioned hinges are derived out of the equations of an one-bladed propeller by superposition. Different types of propellers are compared for time variances at the equations. An unbalanced start up and the stability analyses (FLOQUET) of an experimental one-bladed propeller illustrate the need of considering the interaction of the motions of nacelle or hub and blade.

85-268

Non-steady Forces in Turbomachine Stage

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Indian Inst. of Technology, New Delhi 110016, India

Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept. 11-13, 1984, pp 243-253, 9 figs, 18 refs

KEY WORDS: Rotorblades (turbomachinery), Force coefficients, Fluid-induced excitation

This paper is concerned with the non-steady forces in a turbine stage due to flow interference between stator and rotor rows. The analysis is made following the Kemp-Sears procedure, for a flat plate stage in subsonic compressible flow. Both upwash and downwash effects are included. The analytical results obtained are presented graphically as a function of stage gap ratio, blade spacing ratio and Mach number. A modified hydraulic analogy is used to model the flat plate stage on a rotating water table and the trends of experimental results have confirmed theoretical predictions.

85-269

Acoustically Excited Vibration of Compressor Blades

R. Parker, S.A.T. Stoneman
Univ. College of Swansea, UK

Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 233-242, 9 figs, 14 refs

KEY WORDS: Compressor blades, Acoustic excitation, Vortex shedding

As the design of axial flow compressors has advanced over the last few years a hitherto unrecognized type of blade vibration excitation has been observed at off-design operating speeds. Observations on multi-stage research compressors have disclosed significant vibration stresses associated with pressure waves in the compressor annulus which can be described as rotating acoustic modes. These effects are discussed.

85-270

Numerical Analysis of Transient Responses in Blade Dynamics

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Institut fur Mechanik, Gesampthochschule Kassel-Universitat, Kassel, W. Germany
Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 255-267, 10 figs, 14 refs

KEY WORDS: Turbine blades, Beams, Transient response, Numerical analysis

A numerical model for the calculation of transient responses of turbine blades is presented on the basis of an extended beam theory.

85-271
On the Long Arc Coupling of Steam Turbine Buckets
O. Tuncel, R.A. Walter, A.B. Dobb, Jr.
General Electric Co., Lynn, MA
Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 319-326, 8 figs, 6 refs

KEY WORDS: Turbine blades, Steam turbines, Design techniques

A large percentage of steam turbine bucket problems experienced in industry occur in low-per rev (LPR) stages. An LPR stage is one in which the fundamental mode frequency of the grouped buckets is in the range of low multiples of turbine speed. This paper discusses the effect of long arc coupling as applied to variable speed steam turbine buckets. The study discusses the harmonic coupling of buckets for the fundamental mode and extends the design concepts to include the impact of higher modes which can be as critical as the fundamental mode. The concepts were evaluated in a full scale test program and results have been verified by field experiences. The paper also discusses these experimental evaluations and field experiences.

85-272
Some Practical Aspects of the Interpretation of Coupled LP-Stage Vibration
J. Wachter, R. Pfeiffer, J. Jarosch
Institiut fur Thermische Stromungsmaschinen, Universitat Stuttgart, W. Germany
Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 311-317, 11 figs, 11 refs

KEY WORDS: Turbine blades, Steam turbines, Coupled response

The paper deals with the vibration characteristics of a steam turbine LP-stage whose blades are coupled by lashing pins or lacing wire. This LP-wheel was subjected to various investigations under static and operating conditions. The investigations show that in the operation range all modes with high alternating stresses can be assigned to the first vibration family.

85-273
Analysis of Propeller Blade Dynamic Stresses
Jui-Fang Kuo
Ph.D. Thesis, The Univ. of Michigan, 15 pp (1984), DA8412187

KEY WORDS: Propeller blades, Marine propellers, Fluid-structure interaction

A method was developed for predicting the dynamic stress field in marine propeller blades rotating through a non-uniform ship wake For this analysis, the propeller geometric characteristics, operating conditions, and the ship wake are assumed to be known in advance.

85-274
Model of Rotor Blade First Natural Flapping Response for Up to Three/Rev Excitations
J.B. Wilkerson
David W. Taylor Naval Ship Res. and Dev. Ctr., Bethesda, MD
Rept. No. DTNSRDC/ASED-83/09, 26 pp (Dec 1983), AD-A141 725

KEY WORDS: Propeller blades, Helicopters, Natural frequencies

Thus far, all performance calculations for the X-Wing vertical takeoff concept have used a rigid, nonflapping blade analysis. At this stage in the concept development, the flapping degree of freedom should be included for increased accuracy. Thus, a relatively simple set of equations is developed to relate rotor blade aerodynamic moments and blade flapping response which provides rapid evaluation of the blade dynamics and the resulting changes in aerodynamic loading. A case is examined for the critical conversion advance ratio, and the first order dynamic response is shown for a range of blade natural frequencies. It is shown that a blade natural frequency higher than 2-per-day is desired.

85-275

Synthesized Airfoil Data Method for Prediction of Dynamic Stall and Unsteady Airloads

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Vertica, 8 (2), pp 93-118 (1984), 16 figs, 1 table, 14 refs

KEY WORDS: Airfoils, Stalling, Time domain method, Propeller blades, Helicopters

A detailed analysis of dynamic stall experiments has led to a set of relatively compact analytical expressions, called synthesized unsteady airfoil data. They accurately describe in the time-domain the unsteady aerodynamic characteristics of stalled airfoils. Under the present study, unsteady drag data were synthesized which provided the basis for successful expansion of the formulation to include computation of the unsteady pressure drag of airfoils and rotor blades. An improved prediction model for airfoil flow reattachment was incorporated in the method. The results obtained clearly indic^te that it is feasible to generalize the empirical parameters embedded in the present method over a range of angle of attack, Mach number, airfoil shape and sweep angle. However, the empirical parameters, corresponding to the various data sets synthesized to date were found to be insufficient for generalization of the parameters.

85-276

Acoustic Measurements of a Full-Scale Rotor with Four Tip Shapes. Volume 2: Appendices C, D, E and F

M. Mosher
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Rept. No. A-9602-V-2, NASA-TM-85878-V-2, 347 pp (Apr 1984), N84-25426

KEY WORDS: Blades, Propeller blades, Sound measurement

A full scale helicopter with four different blade tip geometries is tested in a 40- by 80-foot wind tunnel. Performance, loads, and noise are measured. The four tip shapes tested were rectangular, tapered, swept, and swept/tapered.

85-277

Impact and Bending of a Rigid-Plastic Fan Blade

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J. Appl. Mech., Trans. ASME, 51 (3), pp 501-504 (Sept 1984), 6 figs, 4 refs

KEY WORDS: Fan blades, Impact response

A rigid-plastic fan blade is subjected to a transverse impact force at the tip in addition to radial centrifugal forces caused by fan rotation. Large and small deflection formulations for inplane bending of the cantilevered blade are calculated and compared.

BEARINGS

85-278

Stability of Offset Journal Bearing Systems

J.F. Booker, S. Govindachar
School of Mechanical and Aerospace Engrg., Cornell Univ., NY
Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York Heslington, Yorkshire, Sept 11-13, 1984, pp 269-275, 9 figs, 1 table, 6 refs

KEY WORDS: Journal bearings, Stability

Novel offset designs offer attractive possibilities in several applications for which conventional journal bearings are only marginally satisfactory. One such prototypical problem in rotating machinery is the support of a rigid (massive) rotor turning at high speed under a fixed (gravity) load. This classic case is studied through a (dimensional) numerical example and (nondimensional) parametric studies. Stability of full journal bearing systems is shown to be both significantly improved by moderate offsets and fairly insensitive to small departures from optimal design values.

85-279
The Prediction and Measurement of Bearing Transfer Functions at High Frequencies
C.J. Jenkins, L.V. Embling, D.A. Cordner
Admiralty Res. Establishment (Teddington), Queens Rd., Teddington, Middlesex, UK
Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 295-302, 5 figs, 3 refs

KEY WORDS: Fluid-film bearings, Transfer functions, Stiffness coefficients, Damping coefficients

Nonlinear journal bearing coefficients have been used to estimate the transfer functions across a hydrodynamic journal bearing and to predict the level of modulation of vibration when transmitted across the bearing. The predictions are compared with measurements made on a test rig.

85-280
Kalman Filters Applied to Time-Domain Estimation of Linearized Oil-Film Coefficients
M.N. Sahinkaya, C.R. Burrow
Dept. of Dynamics and Control, Univ. of Strathclyde, Glasgow
Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 109-118, 4 figs, 2 tables, 20 refs

KEY WORDS: Oil film bearings, Error analysis, Kalman filter technique, Least squares method

Some experimental results obtained from a squeeze-film bearing are used to assess the new approach to the estimation of oil-film parameters.

85-281
The Effect of Manufacturing Tolerances on the Stability of Profile Bore Bearings
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The Glacier Metal Co., Ltd., Wembley, Middlesex, UK
Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 287-293, 8 figs, 2 tables, 4 refs

KEY WORDS: Fluid-film bearings, Oil whirl phenomena, Self-excited vibrations

Profile bore journal bearings are used to suppress rotor instability caused by oil film whirl. The effect of manufacturing tolerances on the clearances in a tilted 3-lobe bearing and and offset halves bearing is demonstrated. Results show the effects of these dimensional variations and how these changes affect the instability threshold speed.

85-282
Investigation of the Dynamic Properties of an Elastomer Bush

A.J. Gaughan, D.A. Phipps
Bristol Univ., UK
Rept. No. BU-283, 38 pp (June 1983), N84-24543

KEY WORDS: Bushings, Linings, Damping coefficients, Stiffness coefficients

The dynamic properties (i.e., damping and stiffness) of an elastomer bush were investigated by using the aerodynamics forces on the transmission lines to damp a pendulum. The angular displacement was measured by a rotary transducer and recorded on an ultra-violet recorder.

85-283
Dynamic Stability of a Passive Magnetic Suspension with an Eight-Pole Stator
J. Arai
Shizuoka Univ., 3-5-1 Jyohoku, Hamamatsu, Japan
Bull. JSME, 27 (229), pp 1506-1512 (July 1984), 14 figs, 6 refs

KEY WORDS: Bearings, Magnetic suspension techniques

A passive magnetic radial bearing with an eight-pole stator is statically stable But its inherent damping characteristics are not sufficient to prevent dynamic instability. The dynamic stability of the magnetic bearing is commonly attained by introducing the friction of a mechanical viscous fluid. Though the static performance in this type of magnetic bearing has been theoretically analyzed by some investigators, its dynamic stability has not been fully determined. This study presents an analysis of the dynamic characteristics of a passive magnetic radial bearing with an eight-pole stator.

85-284
Dynamic Properties of Externally-Pressurized Gas Journal Bearings with Circular Slot Restrictors
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The Science Univ. of Tokyo, 1-3 Kagurazaka, Shinjuku-ku, Tokyo, Japan
Bull. JSME, 27 (229), pp 1537-1543 (July 1984), 12 figs, 6 refs

KEY WORDS: Journal bearings, Gas bearings

The externally-pressurized gas journal bearings with circular slot restrictors are investigated theoretically and experimentally to determine their dynamic properties. The theoretical analyses are presented for a single and double row admission bearing. The accuracy of the theoretical method shows that the present theoretical method can accurately predict the dynamic properties of a gas journal bearing with a circular slot restrictor.

GEARS

85-285
Dynamic Loads in Gear Teeth
A.W. Lees
Central Electricity Generating Board, South Western Region, Bristol
Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 73-79, 5 figs, 7 refs

KEY WORDS: Gear teeth, Geometric imperfection effects

A method is presented to model the dynamics of machinery involving gears, given the error profile on those gears. The formalism is developed in terms of the physical geometrical errors on the components of the train, rather than the more usual approach using transmission error. The dynamic behavior of the complete machine is expressed in terms of the properties of the assembly as a whole. The relationship between the method presented and transmission error approaches is shown to be rather complex. It is shown that the method is of particular help in predicting the machine's behavior in the lower range

of frequency, where vibrational modes extend over a considerable proportion of the complete rotor train.

85-286
Dynamic Behavior of High Speed Gears
F. Kucukay
Technical Univ. of Munich, W. Germany
Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 81-90, 13 figs, 11 refs

KEY WORDS: Gears, Parametric vibration

The estimation of the operating reliability of gears affords knowledge about the load capacity of the toothing. The predetermination of tooth static and dynamic forces in combination with a dynamical analysis is of main importance in gear design. Confidence level of the model used herein is demonstrated by comparison of the theory with experiments.

85-287
Separating Excitation and Structural Response Effects in Gearboxes
R.B. Randall
Bruel and Kjaer, Naerum, Denmark
Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 101-107, 6 figs, 12 refs

KEY WORDS: Gear boxes, Signal processing techniques, Structural response, Monitoring techniques

The paper indicates a method for dividing a measured gearbox vibration signal into a forcing function and structural response effect. Analysis shows that the excitation concentrates in well-defined regions in the cepstrum, allowing the response to be determined by curve-fitting the remainder. The method would be very valuable for condition monitoring of machines operating at constant speed and load where the forces cannot be measured directly.

FASTENERS

85-288
Fatigue Behavior of Welded Joints Subjected to Variable Amplitude Stress
J.M. Joehnik, K.H. Frank, J.A. Yura
Texas Univ., Austin, TX
Rept. No. CTR-3-5-81-306-1, FHWA/TX-83/24-306-1, 102 pp (Oct 1983), PB84-207620

KEY WORDS: Welded joints, Fatigue life, Variable amplitude excitation

The fatigue behavior of welded steel tees loaded in cantilever bending was examined using simple variable amplitude stress waveforms. These waveforms were developed by superimposing two sine wave signals, i.e., a high frequency/low amplitude signal upon a low frequency/low amplitude signal upon a low frequency/high amplitude signal. The test program involved changing the relative size and frequency of these two sine signals. These tests were to determine the effect that smaller high frequency stress cycles would have upon the fatigue life associated with a major stress cycle.

85-289
Effect of Mean Stress on Fatigue-Crack Growth in Cruciform-Welded Joints Under Non-Stationary Narrow-Band Random Loading
L.P. Pook
National Engrg. Lab., East Kilbride, Scotland
Rept. No. NEL-690, 37 pp (1983), PB84-201102

KEY WORDS: Welded joints, Fatigue tests, Crack propagation, Random excitation

Some fatigue tests were carried out in room temperature air at zero and high mean-stress on unstress-relieved cruciform-welded steel joints. The load history used consisted of four different levels of stationary narrow-band random loading arranged in rising and falling sequence, with an overall block length of 100,000 cycles. The results imply that at high mean stress cracks may only open on the positive half cycle, but an explanation must await an adequate elastic-plastic analysis.

SEALS

85-290
Identification of Stiffness, Damping and Mass Coefficients for Annular Seals
R. Nordmann, H. Massmann
Univ. of Kaiserslautern, Fed. Rep. of Germany
Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 167-181, 11 figs, 1 table, 5 refs

KEY WORDS: Seals, Parameter identification techniques, Stiffness coefficients, Damping coefficients, Mass coefficients

An identification procedure is applied to the determination of dynamic coefficients of annular turbulent seals in turbopumps. Measurements were carried out at a built test rig. The system's responses to impact forces, that the motions of the seal surfaces, are used to calculate complex frequency response functions. Finally an analytical model, depending on the seal parameters, is fitted to the measured data in order to find the dynamic coefficients.

85-291
Plain Seal Dynamic Behaviour — Experimental and Analytical Results
M. Falco, G. Mimmi, B. Pizzigoni, G. Marenco
Polytechnic of Milan, Italy
Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 151-158, 11 figs, 10 refs

KEY WORDS: Seals, Stiffness coefficients, Damping coefficients

The results of theoretical-experimental research carried out to determine the equivalent stiffness and damping coefficients of plain fluid film seals are described in this paper. The experimental results are compared to those obtained with an analytical model based on Reynolds equation.

85-292
Finite-Length Solutions for the Rotordynamic Coefficients of Constant-Clearance and Convergent-Tapered Annular Seals
D.W. Childs
Texas A & M Univ., College Station, TX
Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Heslington, Yorkshire, Sept 11-13, 1984, pp 223-231, 8 figs, 2 tables, 13 refs

KEY WORDS: Seals, Damping coefficients, Stiffness coefficients, Turbulence, Geometric effects

A combined analytical-computational method is developed to calculate the pressure field and dynamic coefficients for high-pressure annular seals which are typical of neck-ring and interstage seals employed in multistage centrifugal pumps. Experimental results are presented for four annular seals beginning with a constant-clearance seal. THree tapered seal configurations are obtained by increasing the entrance clearance while holding the exit clearance constant. The test results show that leakage increases and damping decreases as the taper angle is increased. However, contrary to theoretical predictions, the direct stiffness remains relatively constant as the taper angle increases.

85-293
Static and Dynamic Characteristics of Annular Plain Seals
S. Kaneko, Y. Hori, M. Tanaka
Technological Univ. of Nagaoka, Japan
Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 205-214, 7 figs, 1 table, 1 ref

KEY WORDS: Seals, Fluid-induced excitation, Stiffness coefficients, Damping coefficients, Pumps

The static and dynamic characteristics of annular plain seals were investigated theoretically and experimentally in the laminar and turbulent flow regimes. The theory was confirmed to be in good agreement with measurements.

85-294
Experimental Measurement of Lateral Force in a Model Labyrinth and the Effect on Rotor Stability
R.D. Brown, Y.M.M.S. Leong
Heriot-Watt Univ., Edinburg
Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. York, Heslington, Yorkshire, Sept 11-13, 1984, pp 215-222, 8 figs, 19 refs

KEY WORDS: Seals, Fluid-induced excitation, Force measurement, Rotors, Stability

Experimental determination of circumferential pressure in model labyrinth seals demonstrated significant lateral force for parallel eccentricity. Entry swirl was a major influence and theoretical stability calculations indicated the possibility of forward whirl. The ratio of whirl frequency to rotational speed was considerably greater than 0.5.

85-295
Experimental Study on Dynamic Characteristics of Pump Annular Seals
H. Kanki, T. Kawakami
Takasago Technical Inst. of Mitsubishi Heavy Industries Limited, Takasago, Japan
Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 159-166, 12 figs, 3 tables, 9 refs

KEY WORDS: Seals, Pumps

The static and dynamic characteristics of pump annular sears were studied by using special test apparatus and test method.. The characteristics of the various annular seals were solved for rotor dynamics analysis application.

STRUCTURAL COMPONENTS

BEAMS

85-296
Dynamics of Bernoulli-Euler Beams Conveying Compressible Fluid
R.O. Johnson, J.E. Stoneking, T.G. Carley
Oak Ridge Gaseous Diffusion Plant, Oak Ridge, TN
Rept. No. K/TS-11-111, CONF840504-1, 6 pp (1984),
DE84005066

KEY WORDS: Beams, Tubes, Bernoulli-Euler method

The eigenvalue problem associated with the equations of motion of a compressible, fluid-conveying, cantilevered, Bernoulli-Euler beam or tube is solved using Muller's method. Compressibility affects the dynamics of the system through tube aspect ratio and fluid sonic velocity. Parametric studies indicate that aspect ratio has a more pronounced influence on the critical velocity than sonic velocity.

85-297

Forced Vibrations of a Continuous Beam with Ends Elastically Restrained Against Rotation.

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Inst. of Applied Mechanics, 8111-Puerto Belgrano Naval Base, Argentina
Appl. Acoust., 17 (5), pp 345-356 (1984), 7 figs, 8 refs

KEY WORDS: Beams, Periodic Excitation, Approximation methods

A survey of the literature shows that the title problem has not been studied to any great extent. In the present paper an approximate solution is obtained in the case of a beam with ends elastically restrained against rotation and an intermediate support. A sinusoidally varying excitation is assumed.

85-298

Consistent Hydrodynamic Mass for Parallel Prismatic Beams in a Fluid-Filled Container

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J. Pressure Vessel Tech., Trans. ASME, 106 (3), pp 270-274 (Aug 1984), 5 figs, 5 tables, 7 refs

KEY WORDS: Beams, Fluid-filled containers, Fluid-structure interaction, Hydrodynamic response

In this paper, representation of the effects of incompressible fluid on the dynamic response of parallel beams in fluid-filled containers is developed. The technique is illustrated by application to analysis of an experiment involving vibration of an array of four tubes in a fluid-filled cylinder.

85-299

Free Vibration of a Thin-Walled Beam-Shell of Arc Cross-Section

T. Irie, G. Yamada, K. Tanaka
Hokkaido Univ., Sapporo, 060 Japan
J. Sound Vib., 94 (4), pp 563-572 (June 22, 1984), 4 figs, 1 table, 17 refs

KEY WORDS: Beams, Shells, Natural frequencies

The free vibration of a thin-walled beam-shell of arc cross-section is studied by using shell theory and beam theory. The equations of vibration based upon beam theory are also obtained, and the frequency equation is derived analytically. The natural frequencies obtained from the two theories are compared with each other, and the vibration characteristics of the beam-shell are studied.

85-300

Mast Mounted Visual Aids

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Vertica, 8 (2), pp 183-195 (1984), 19 figs, 1 table, 3 refs

KEY WORDS: Helicopters, Beams, Flight tests

Initial flight tests with a spherical mock up, having the same shape, weight and moments of inertia as the actual system were carried out on a BO 105 helicopter with two different rotor mast extensions. A vibration survey over most of the BO 105's flight envelope showed vibrational loads which can be tolerated by the actual system. Investigations of the controllability and stability are also presented. The influence of the rotor plane, vibrational loads and meterological conditions on the performance of the FLIR image is described.

85-301

Dynamic Stability for a Simply Supported Beam Under Periodic Axial Excitation

J.S. Huang, L.H. Hung
Chung-Yuan Christian Univ., Chung-Li, Taiwan, R.O.C.

Intl. J. Nonlin. Mech., 19 (4), pp 287-301 (1984), 13 figs, 15 refs

KEY WORDS: Beams, Periodic excitation, Stability

This paper studies the dynamic stability for a simply supported straight beam under periodic axial excitation by using the averaging method and the Routh-Hurwitz stability criteria.

85-302
Vibration of a Beam Under a Random Stream of Moving Forces
R. Iwankiewicz, P. Sniady
Inst. of Civil Engrg., Technical Univ. of Wroclaw, Wroclaw, Poland
J. Struc. Mech., 12 (1), pp13-26 (1984), 8 figs, 11 refs

KEY WORDS: Beams, Moving loads

The problem of dynamic response of a beam to the passage of a train of concentrated forces with random amplitudes is considered. Force arrivals at the beam are assumed to constitute a Poisson process of events. Thus, the excitation process idealizes vehicular traffic loads on a bridge. An analytical technique is developed to determine the response of the beam.

CYLINDERS

85-303
Wave Forces Acting on a Vertical Circular Cylinder with a Constant Forward Velocity
W. Koterayama
Kyushu Univ., 33 Sakamoto Kasuga, Fukuoka 816, Japan
Ocean Engrg., 11 (4), pp 363-379 (1984)

KEY WORDS: Circular cylinders, Submerged structures, Wave forces, Hydrodynamic excitation

Wave forces acting on submerged circular cylinders moving forward with a constant velocity in regular waves are investigated experimentally. Hydrodynamic forces acting on the cylinder forced to surge in a steady flow are also measured and hydrodynamic coefficients were obtained. Wave force coefficients obtained from wave force measurements are compared with the hydrodynamic coefficients from surging tests, and the similarity and difference between them are discussed. Experiments show that these coefficients are quite different from those of the cylinder without a forward velocity.

85-304
Oblique Vortex Induced Vibration of Cylinders
G.P. Gleed, M.J. Greenman
Dept. of Aeronautical Engrg., Bristol Univ., UK
Rept. No. BU-295, 37 pp (June 1983), N84-25104

KEY WORDS: Cylinders, Vortex-induced vibration, Cables

Vortex shedding over circular cylinders when the motion of the cylinder is constrained at an acute angle to the airflow was investigated. Variation of both amplitude and power input with direction of motion for a cylinder in a varying velocity airflow was investigated.

FRAMES AND ARCHES

85-305
On the Low-Frequency Drumming of Bowed Structures
A.H. Nayfeh
Yarmouk Univ., Irbid, Jordan
J. Sound Vib., 94 (4), pp 551-562 (June 22, 1984), 4 figs, 9 refs

KEY WORDS: Arches, Subharmonic oscillations

The response of bowed structural elements to a two-frequency, transverse load is determined. The effects of both initial curvature and mid-surface stretching are included. Possible large-amplitude low-frequency responses to excitations of such structural elements are investigated: that is, drumming. Specifically the conditions under which the one-half subharmonics of the transverse load can be excited individually or simultaneously are determined. The results are applied to a shallow arch.

85-306
The Estimation of Large Deflections of a Portal Frame Under Asymmetric Pulse Loading
J.L. Raphanel, P.S. Symonds
Brown Univ., Providence, RI 02912
J. Appl. Mech., Trans. ASME, 51 (3), pp 494-500 (Sept 1984), 7 figs, 13 refs

KEY WORDS: Frames, Pulse excitation, Elastic plastic properties

Modifications of a simple elastic-plastic technique are shown which allow estimation *of local deformation in the loaded column* of a portal frame as well as the side-sway deflections of the frame. A wholly elastic response stage provides input to a simplified rigid-plastic solution. Velocity patterns first of local and then of modal (side-sway) type occur. They furnish estimates of final plastic deflections. Emphasis in this paper is put on the inclusion of elastic and viscoplastic effects.

85-307
Dynamic Characteristics of Large Repetitive Framelike Structures
A.H. Nayfeh, M.S. Hartie
Yarmouk Univ., Irbid, Jordan
J. Appl. Mech., Trans. ASME, 51 (3), pp 510-518 (Sept 1984), 12 figs, 1 table, 34 refs

KEY WORDS: Frames, Grids (beam grids), Building block approach, Continuum mechanics

Using a building block approach and starting with a single element, expressions for the energy of various two-dimensional frametype gridwork configurations are derived. These are then used to develop energy equivalent continua for the gridworks. Equations of motion and associated boundary conditions are obtained for the continua. Some dynamic characteristics of these continua are investigated and compared with corresponding results obtained from finite element codes and also with some available theoretical predictions.

MEMBRANES, FILMS, AND WEBS

85-308
Simplified Large Deflection Mode Solutions for Impulsively Loaded, Viscoplastic, Circular Membranes
N. Perrone, P. Bhadra
Catholic Univ., Washington, D.C.
J. Appl. Mech., Trans. ASME, 51 (3), pp 505-509 (Sept 1984), 8 figs, 1 table, 21 refs

KEY WORDS: Membranes, Plates, Dynamic plasticity, Mode approximation technique

The title problem is solved by estimating the maximum strain rate field in a circular membrane associated with a modal velocity condition. One-half the kinetic energy in the system is dissipated. The radial stress may only vary in the radial direction, but is taken as a constant with time at any given location. Correlation of analytically determined results with a series of experiments reported elsewhere is very good. The procedure described here is potentially extendable to any planform membrane shape as well as to axisymmetric shells. The method is applicable to plate problems when membrane effects dominate over bending. A simple general formula for final plate deformation is devised and also agrees well with experimental results.

PLATES

85-309

Multiple Mode Large Amplitude Vibration of Thick Orthotropic Circular Plates

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Intl. J. Nonlin. Mech., 19 (4), pp 341-348 (1984), 4 figs, 5 tables, 11 refs

KEY WORDS: Plates, Large amplitudes, Modal analysis, Transverse shear deformation effects, Rotatory inertia effects

This paper is analytically concerned with the large amplitude vibration of thick orthotropic circular plates incorporating the effects of transverse shear and rotatory inertia. Effects of transverse shear deformation and modal interaction are found to be significant for orthotropic thick plates. The method given here could be extended to the multiple-mode analysis of circular plates with other boundary conditions.

85-310

An Exact Analytical Approach to the Free Vibration Analysis of Rectangular plates with Mixed Boundary Conditions

D.J. Gorman
Univ. of Ottawa, Ottawa, Canada
J. Sound Vib., 93 (2), pp 235-247 (Mar 22, 1984), 4 figs, 4 tables, 7 refs

KEY WORDS: Rectangular plates, Exact methods, Eigenvalue problems

A comprehensive analytical technique is developed for the free vibration analysis of rectangular plates with discontinuities along the boundaries. For illustrative purposes a solution is obtained for plates with edges partially clamped and partially simply supported and plates with edges partially free and partially simply supported. A vast array of first mode eigenvalues is provided for these families of plates. Solutions to the equations are obtained by exploiting a mathematical technique described by the author during an earlier publication. It is shown that eigenvalue matrices are easily generated for a wide range of plates with discontinuities in boundary conditions.

85-311

Axisymmetric Vibration of an Initially Stressed Bimodulus Thick Circular Plate

Ji-Liang Doong, Lien-Wen Chen
National Cheng Kung Univ., Tainan, Taiwan, Rep. of China
J. Sound Vib., 94 (4), pp 461-468 (June 22, 1984), 6 figs, 2 tables, 21 refs

KEY WORDS: Circular plates, Axisymmetric vibrations, Galerkin method

The fundamental frequency of an axisymmetric clamped circular bimodulus thick plate subjected to a combination of a pure bending stress and extensional stress in the plane of the plate is investigated. The governing equations which are obtained by using the average stress method are solved by the Galerkin method. Natural frequencies are compared with the previous results of Irie et al. for ordinary thick plates. The effects of various parameters on the natural frequencies and neutral surface locations are studied. The bimodulus properties are shown to reduce the frequency coefficient significantly.

85-312

A Note on Forced Vibrations of a Circular Plate with Thickness Varying in a Bilinear Fashion

B. Valerga de Grego, P.A.A. Laura
Inst. of Applied Mechanics, Puerto Belgrano Naval Base, 8111 - Argentina
J. Sound Vib., 94 (4), pp 525-530 (June 22, 1984), 1 fig, 3 tables, 8 refs

KEY WORDS: Circular plates, Variable cross section

The title problem is solved for the case where the plate edge is elastically restrained against rotation. Simple polynomial approximations and the Ritz method are used to generate the frequency determinant. The problem is of general interest

in several situations of mechanical and transducer design.

their accuracy. The choice of a best shear coefficient for use in the Mindlin plate theory is considered.

85-313
Generation of Waves in an Elastic Plate by a Torsional Moment and a Horizontal Force
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J. Sound Vib., 93 (2), pp 161-187 (Mar 22, 1984), 12 figs, 2 tables, 11 refs

KEY WORDS: Plates, Elastic properties, Wave generation

An approximate solution is determined for the motion of an infinite elastic plate. It is excited by a torsional moment (with the axis of the moment normal to the plate) and by a horizontal force (parallel to the plate). The driving moment and force are sinusoidal in time and applied to a small rigid indenter with a circular case, fixed to the plate.

85-314
Vibrations of Thick Free Circular Plates, Exact Versus Approximate Solutions
J.R. Hutchinson
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J. Appl. Mech., Trans. ASME, 51 (3), pp 581-585 (Sept 1984), 8 figs, 1 table, 12 refs

KEY WORDS: Circular plates, Natural frequencies, Exact methods, Approximation methods

An exact solution for the natural frequencies of a thick free circular plate is compared to approximate solutions. The exact solution is a series solution of the general linear elasticity equations that converges to the correct natural frequencies. The approximate solutions to which this exact solution is compared are the Mindlin plate theory and a modification of a solution method proposed by Pickett. The comparisons clearly show the range of applicability of the approximate solutions as well as

85-315
A Collocation Approach to Plate Vibration
S.F. Ng, T.A. Sa
Univ. of Ottawa, Ottawa, Ontario, Canada
J. Struc. Mech., 12 (1), pp 43-57 (1984), 5 figs, 3 tables, 9 refs

KEY WORDS: Plates, Collocation method, Least square method

The conventional simple but crude method of collocation is greatly improved by a least-square augmentation. Simplicity in application and good accuracy of the proposed collocation least-square scheme is demonstrated. Numerical and graphical results are presented and compared with existing solutions.

SHELLS

85-316
Seismic Response Analysis of Cylindrical Tanks with Initial Irregularities on Side Walls
H. Zui, T. Shinke
Koke Steel, Ltd., Koke, Japan
ASME Paper No. 84-PVP-70

KEY WORDS: Tanks (containers), Geometric effects, Seismic response

The theory is developed in this paper to integrate change of wall thickness and roof condition of tanks. The behavior of rigid base flexible tanks under horizontal seismic condition is predicted.

85-317
Application of the Momentum Balance Method in Seismic Analysis of Tanks

M.A. Haroun
Univ. of California, Irvine, CA
ASME Paper No. 84-PVP-69

KEY WORDS: Tanks (containers), Seismic analysis

The momentum balance method offers a simple approach for the calculation of hydrodynamic pressures. Distinction is made between the apparent masses based on horizontal momentum balance and vertical momentum balance.

85-318
Axisymmetric Vibrations of Thin Shells of Revolution
K. Suzuki, N. Kikuchi, T. Kosawada, S. Takahashi
Yamagata Univ., Yonezawa, Japan
Bull. JSME, 27 (227), pp 974-979 (May 1984), 11 figs, 9 refs

KEY WORDS: Shells of revolution, Axisymmetric vibrations, Natural frequencies, Mode shapes

By using thin shell theory, the axisymmetric vibrations of thin barrel-like shells of revolution are analyzed. The frequencies and the mode shapes are obtained for symmetric shells with both ends clamped and simply supported.

85-319
Free Vibration of a Clamped-Clamped Circular Cylindrical Shell Partially Filled with Liquid
N. Yamaki, J. Tani, T. Yamaji
Tohoku Univ., Sendai, Japan
J. Sound Vib., 94 (4), pp 531-550 (June 22, 1984), 8 figs, 4 tables, 30 refs

KEY WORDS: Cylindrical shells, Fluid-filled containers, Natural frequencies

Accurate analyses are presented for the linear free vibration of a clamped cylindrical shell partially filled with an incompressible, inviscid liquid. For the vibration of the shell itself, the modified Donnell equations were used. Excellent agreement between theory and experiment is demonstrated for the lower order natural vibrations dominated by the shell vibration. Effects of the initial hoop stress as well as the condition of the liquid surface on the natural frequencies are also examined.

85-320
Optimal Location of Additional Supports for Plastic Cylindrical Shells Subjected to Impulsive Loading
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Intl. J. Nonlin. Mech., 19 (4), pp 323-330 (1984), 2 figs, 14 refs

KEY WORDS: Cylindrical shells, Supports, Optimization

Necessary optimality conditions for location of the additional supports, restricting the dynamic response of a rigid perfectly plastic cylindrical shell subjected to an initial transverse velocity, are deduced. A particular case associated with the uniform initial impulse is examined in detail.

85-321
Optimal Forms of Shallow Shells with Circular Boundary, Part I: Maximum Fundamental Frequency.
R.H. Plaut, L.W. Johnson, R. Parbery
Virginia Polytechnic Inst. and State Univ., Blacksburg, VA 24061
J. Appl. Mech., Trans. ASME, 51 (3), pp 526-530 (Sept 1984), 8 figs, 11 refs

KEY WORDS: Spherical shells, Optimization, Natural frequencies

Thin, shallow, elastic shells with given circular boundary are considered. The axisymmetric shell form which maximizes the fundamental frequency of vibration is examined.

85-322
Thermally Induced Vibrations of Viscoelastic Shallow Shells
J. Mazumdar, D. Hill
The Univ. of Adelaide, Adelaide, South Australia, Australia
J. Sound Vib., 93 (2) pp 189-200 (Mar 22, 1984), 5 figs, 12 refs

KEY WORDS: Shells, Temperature effects

A method for the study of thermally induced vibrations of viscoelastic shallow shells of arbitrary shaped plane-form is proposed. The response of a shallow shell with rectangular as well as elliptical base to the sudden application of a temperature distribution on the surface of the shell is discussed. For rapidly applied heat inputs, an approximate analysis for its rapid estimation is also presented. All details are illustrated by graphs.

PIPES AND TUBES

85-323
Damping Test Results for Straight Sections of 3-inch and 8-inch Unpressurized Pipes
A.G. Ware, G.L. Thinnes
EG and G Idaho, Inc., Idaho Falls, ID
Rept. No. EGG-2305, 69 pp (Apr 1984), NUREG/CR-3722

KEY WORDS: Pipes, Nuclear reactor components, Damping coefficients

A series of vibrational tests on unpressurized 3-in. and 8-in. Schedule 40 carbon steel piping was conducted to determine the changes in structural damping due to various parametric effects. The 33-ft straight sections of piping were supported at the ends. Additionally, intermediate supports comprising spring, rod, and constant-force hangers, as well as a sway brace and snubbers, were used. Excitation was provided by low-force-level hammer impacts, a hydraulic shaker, and a 50-ton overhead crane for snapback testing. Data were recorded using acceleration, strain, and displacement time histories. This report presents test results showing the effect of stress level and type of supports on structural damping in piping.

85-324
Method of Pipe Whip and Impact Analyses
R.C. Chun, T.Y. Chuang
Lawrence Livermore National Lab., CA
Rept. No. UCRL-90049, CONF-840647-3, 14 pp (Nov 21, 1983), DE84003897

KEY WORDS: Pipes, Computer programs, Impact response

The computer code WIPS results are in excellent agreement with the experimental data and the French computer code TEDEL. This justifies the use of its pipe element in conjunction with its U-bar element in a simplified method of impact analyses.

85-325
A Technique for Visual Inspection of Pipe Vibrations
W. Taylor
GDS Associates, Chicago, IL
ASME Paper No. 84-PVP-85

KEY WORDS: Pipes, Nuclear power plants, Vibration measurements

This paper describes techniques and an apparatus designed to qualify inspectors for pre-operational testing walkdowns of piping systems in nuclear power plants. Data are presented showing a large variation in the visual perception threshold among 36 candidate inspectors.

85-326
Response Margins of the Dynamic Analysis of Piping Systems
J.J. Johnson, B.J. Benda, T.Y. Chuang, P.D. Smith
Lawrence Livermore National Lab., CA

Rept. No. UCID-20067, 71 pp (Apr 1984), DE84010774

KEY WORDS: Piping systems, Nuclear power plants

This report describes the three piping systems of the Zion nuclear power plant which formed the basis of the present study. Response from these models provided input to the piping models.

85-327
Decoupling Procedure for Seismic Analysis of Piping Systems
M.L. Aggarwal, W.P. Wong, C.T. Ng
Ontario Hydro, Canada
ASME Paper No. 84-PVP-97

KEY WORDS: Piping systems, Seismic analysis, Nuclear power plants

A practical engineering approach that is response spectra dependent has been outlined for developing decoupling criteria applicable to large piping systems where traditional methods were proven to be overly conservative. The proposed procedure is easy to implement and use, and it has been found useful and acceptable for design of many nuclear power plant piping systems.

85-328
Experiments on Tubes Conveying Fluid
J.A. Jendrzejczyk, S.S. Chen
Argonne National Lab., IL
Rept. No. CONF-840647-1, 34 pp (1984), DE84004031

KEY WORDS: Tubes, Fluid-filled containers

Tests are conducted for tubes conveying fluid for six types of support conditions. The objectives are to understand the dynamic characteristics of such systems for different support conditions and to examine the transition from one instability mechanism to another.

DUCTS

85-329
An Experimental Evaluation of Noise Reduction by Scattering in Low Velocity Ducts
M.J. Hood
Bolton Inst. of Higher Education, Deane Rd., Bolton BL3 5AB, Great Britain
Appl. Acoust., 17 (5), pp 357-363 (1984), 6 figs, 4 refs

KEY WORDS: Ducts, Noise reduction, Sound waves, Wave scattering

This paper presents the results of an experimental assessment of both conventional absorption and Bragg scattering techniques. The reduction of noise transmission by a fan in a short, low velocity duct connecting two reverberant rooms is studied. The system appears to work equally well with externally generated sources of sound. The maximum attenuation with eight scatterers is found to be about 12 dB at the Bragg frequency.

BUILDING COMPONENTS

85-330
Evaluation of Sound Absorbing Coefficients in a Reverberant Room by Computer-Ray Simulation
G. Benedetto, R. Spagnolo
Istituto Elettrotecnico Nazionale Galileo Ferraris, Corso Massimo d'Azeglio 42, Torino, Italy
Appl. Acoust., 17 (59), pp 365-378 (1984), 11 figs, 30 refs

KEY WORDS: Sound waves, Wave absorption, Rooms

Standardized methods for the measurement of the sound absorption coefficient of materials in a reverberant room use well known relations. This paper proposes a computer-ray tracing model. It operatively defines the randomization strength of room

design. Lastly, an alternative approach is suggested for evaluating the sound absorption coefficient, based on the characterization of the reverberant room by its own calibration curve.

85-331
Blast Loadings of Emergency Exits for Air-Raid Shelters Type E
E. Edin, J.E. Jonasson
Foersvarets Forskningstalt, Stockholm, Sweden
Rept. No. FOA-C-20530-D4(D6), ISSN-347-3694, 42 pp (Feb 1984), N84-25103 (In Swedish)

KEY WORDS: Doors, Protective shelters, Blast resistant structures, Blast loads

Standard emergency exit Type-E for air raid shelters were tested with short duration blast waves from detonating 48 kg high explosive Comp B/TNT charges at 2.3 and 3 m distance. The exit was undamaged and gas tight after the loading, but not with a cheaper design of the holding bolts.

85-332
Random Vibrations of Multicomponent Structures
E.K. Dimitriadis
Ph.D. Thesis, Georgia Inst. of Technology, 157 pp (1984), DA8411314

KEY WORDS: Structural members, Random vibrations, Statistical energy methods

The response of coupled structural members of a complex structure subjected to random loads, is often estimated by approximate methods based on the concepts of Statistical Energy Analysis (SEA). To examine the fundamental and other SEA assumptions, the problem of two coupled plates is rigorously formulated and solved in terms of SEA variables. Results are presented for the power flow and vibrational energies. Experimental measurements conducted on an L-shaped aluminum plate, randomly excited by an electromagnetic vibration exciter are reported. Theoretical and experimental results are compared between themselves and with the usual SEA approximate predictions. It is demonstrated that the analytical model can yield an understanding of the conditions under which the SEA assumptions are applicable.

85-333
Air Blast Loadings on Building Elements from Detonating 8.4 Kg Comp High Explosive Charges.
H. Axelsson, B. Tollbom
Foersvarets Forskningsanstalt, Stockholm, Sweden
Rept. No. FOA-C-20522-D4, ISSN-347-3694, 85 pp (Nov 1983), N84-25102 (In Swedish)

KEY WORDS: Structural members, Blast loads

Pressure time histories on a test bench for blast loading of building elements were measured for 8.4 kg CompB high explosive charges detonated close to the ground surface at 5 to 17 m distance in front of the test bench. Pressures, impulses and durations for the overpressure and underpressure phases are presented and are compared with data for a free air TNT burst.

ELECTRIC COMPONENTS

CONTROLS (SWITCHES, CIRCUIT BREAKERS)

85-334
Digital Simulation of a Coulomb-Damped Hydraulic Servosystem
J.L. Shearer
The Pennsylvania State Univ., University Park, PA 16802

J. Dynam. Syst., Meas. Control, Trans. ASME, 105 (4), pp 215-221 (Dec 1983), 11 figs, 5 refs

KEY WORDS: Hydraulic servomechanisms, Digital simulation, Coulomb friction

A valve-controlled ram-type servosystem employing position feedback with an electrohydraulic servovalve and servoamplifier is modeled to simulate with a digital computer all of the possibly significant physical characteristics of such a system. Turbulent flow in certain connecting passages, distributed-parameter supply line dynamics, and Coulomb-type dry friction in the ram and mass load are included. The simulated responses are compared with corresponding measured responses of the real system for the case of a single-period sawtooth wave input. It is shown how system stability can become marginal when small amplitude inputs are used.

ELECTRONIC COMPONENTS

85-335

Seismic Investigation of Electrical Raceway Components

F. Elsabee, L. Serdar, Jr., D. Williams
URS/John A. Blume & Associates, W. Peabody, MA
ASME Paper No. 84-PVP-43

KEY WORDS: Electric raceways, Nuclear power plants, Seismic excitation

The structural integrity of flexible electrical raceway systems in nuclear facilities subjected to seismic loads is investigated in an extensive analytical and testing program.

DYNAMIC ENVIRONMENT

ACOUSTIC EXCITATION

85-336

Low Flight Speed Fan Noise from a Supersonic Inlet

R.P. Woodward, F.W. Glaser, J.G. Lucas
NASA Lewis Res. Ctr., Cleveland, OH
J. Aircraft, 21 (9), pp 665-672 (Sept 1984), 19 figs, 15 refs

KEY WORDS: Fan noise, Aircraft noise, Sound propagation, Experimental data

A model supersonic inlet with auxiliary inlet doors and boundary-layer bleeds was acoustically tested in a simulated low-speed flight up to Mach 0.2 and in an anechoic wind tunnel. A JT8D refan model was used as the noise source. Data were also taken for a CTOL inlet and an annular inlet with simulated centerbody support struts. Inlet operation with open auxiliary doors increased the blade passage tone by about 10 dB relative to the closed door configuration although noise radiation was primarily through the main inlet rather than the doors. Numerous strong spikes in the noise spectra were associated with the bleed system and were strongly affected by the centerbody location. The supersonic inlet appeared to suppress multiple pure tones.

85-337

Techniques and Instrumentation for the Measurement of Transient Sound Energy Flux

P.S. Watkinson
Southampton Univ., UK
Rept. No. ISVR-TR-122A, 72 pp (Dec 1983)

KEY WORDS: Industrial facilities, Noise measurement, Machinery noise

The evaluation of sound intensity distributions, and sound powers, of essentially continuous sources was studied.

85-338
Wind-Generated Noise in Shallow Water
M.C. Ferla, W.A. Kuperman
SACLANT ASW Res. Ctr., La Spezia, Italy
Rept. No. SACLANTCEN-SR-79, 21 pp (Apr 1, 1984), AD-A141 981

KEY WORDS: Sound waves, Underwater sound, Wind-induced excitation

An experiment was conducted in a shallow water region of the Mediterranean Sea to study wind-generated noise. In addition to measuring the noise field, propagation-loss data were collected and used in a detailed modelling of the environment.

85-339
Acoustical Transmission by Parallelopiped-Assembled Structures (Transmission acoustique par des structures assemblees parallelepipediques
B. Guerin, C. Lesueur
Laboratoire Vibrations-Acoustique INSA-Lyon, Batiment 303, 20, avenue Albert-Einstein, 69621 Villeurbanne Cedex, France
Acustica, 55 (5), pp 285-292 (Aug 1984), 6 figs, 1 table, 9 refs (In French)

KEY WORDS: Slabs, Parallelepiped bodies, Sound waves, Wave transmission

The transmission of an internal excitation by a parallelopiped structure constructed of slabs of the same thickness is examined.

85-340
Sound Attenuation by Wide Barriers on the Ground
P. Rousseaux
Montefiore Inst., Univ. of Liege, Bat. B 28, Sart-Tilman (Liege 1), Belgium
Acustica, 55 (5), pp 293-300 (Aug 1984), 11 figs, 5 refs

KEY WORDS: Noise barriers, Sound waves, Wave attenuation

The sound attenuation produced by a thick barrier can be calculated by different methods. In this paper Maekawa's empirical method, Kurze's empirical method, and the method due to Pierce based on Keller's geometrical theory of diffraction are examined. An experimental scale model study is carried out in order to test the validity of these methods are examined. Pierce's method appears to be the most accurate one. A method for calculating the attenuation produced by a barrier placed on a reflecting surface is then developed according to the image sources and interference theories. The same method is also applied to a barrier of finite length configuration.

85-341
Research on a Noise Control Device (1st Report, Fundamental Principle of the Device)
K. Mizuno, H. Sekiguchi, K. Iida
Noise and Vibration Control Dept., Bridgestone Co., Ltd., 1 Kashio cho Totsuka ku Yokohama City, Japan
Bull. JSME, 27 (229), pp 1499-1505 (July 1984), 20 figs, 2 refs

KEY WORDS: Noise reduction, Traffic noise, Machinery noise

This study is concerned with a newly developed facility for controlling noise propagation and thereby producing wide region of reduced sound power. It is expected to be effective in alleviating railroad noise, highway noise, and machine noise. In this paper, the structure and principle of the facility are described along with technical data for its practical application.

85-342
Nearfield Pressures and Surface Intensity for Cylindrical Vibrators
P.R. Stepanishen, Huo-Wang Chen
Ocean Engrg. Dept., Univ. of Rhode Island, Kingston, RI 02881
J. Acoust. Soc. Amer., 76 (3), pp 942-948 (Sept 1984), 6 figs, 15 refs

KEY WORDS: Sound waves, Wave radiation, Green function, Fast fourier transform

A numerical approach is presented to evaluate the acoustic nearfield of cylindrical vibrators with specified harmonic radial velocity distributions. The approach is based on the use of a combined Green's function and FFT method. Numerical results are presented to illustrate the spatial characteristics of the acoustic fields and power density of finite length vibrators with axisymmetric and nonaxisymmetric distributions.

85-343

Nonlinear Scattering of Acoustic Waves by Vibrating Surfaces

J.C. Piquette, A.L. Van Buren
Naval Res. Lab., Underwater Sound Reference Detachment, P.O. Box 8337, Orlando, Fl 32856
J. Acoust. Soc. Amer., 76 (3), pp 880-889 (Sept 1984, 12 figs, 16 refs

KEY WORDS: Sound waves, Wave scattering

The problem of the scattering of acoustic waves by a vibrating surface surrounded by a fluid was investigated. Theoretical results were obtained for the specific case of a plane wave normally incident on an infinitely long cylinder vibrating uniformly and harmonically in the radial direction. In the present study, an expression for the difference-frequency wave was obtained using the simple-source formulation of the nonlinear wave equation subject to the appropriate boundary conditions. The expression was evaluated numerically for specific parameters and the results are presented graphically. Efforts to experimentally confirm the theoretical predictions were inhibited by the presence of previously unsuspected levels of hydrophone nonlinearity.

SHOCK EXCITATION

85-344

Blast Loading on Above Ground Barricaded Munition Storage Magazines

C.N. Kingery, G. Bulmash, P. Muller
Army Armament Res. and Dev. Ctr., Aberdeen Proving Ground, MD
Rept. No. ARBRL-TR-2557, SBI-AD-F300 427, 66 pp (May 1984), AD-A141 677

KEY WORDS: Storage, Ammunition, Blast loads

This report presents the results of a study designed to determine the blast loading on above ground munition storage magazines. Blast loading with and without the donor magazine over the charge was documented.

85-345

Concrete Behavior Under Dynamic Tensile-Compressive Load

P.F. Mlakar, K.P. Vitaya-Udom, R.A. Cole
Army Engineer Waterways Experiment Station, Vicksburg, MS
Rept. No. WES/TR/SL-84-1, 62 pp (Jan 1984), AD-A141735

KEY WORDS: Concrete, Seismic response

The significance of dynamic biaxial material behavior of concrete in the study of structural response to seismic and other dynamic loadings is noted. A testing procedure is developed to examine this behavior for the case of monotonic, tensile-compressive loadings.

85-346

Microexplosions in Boreholes

P. Moren
Foersvarets Forskningsanstalt, Stockholm, Sweden
Rept. No. FOA-C-20523-E1, ISSN-347-3694, 17 pp (Dec 1983), N84-25445

KEY WORDS: Seismic tests, Testing techniques

At present micro explosions are the only known source that provides sufficient energy for large scale seismic crosshole measurements. Results from a test of nondestructiveness on bore-hole walls from

micro explosions are summarized. From geophysical well loggings in the holes it was found that only micro explosions with yields of 100 g and greater have a measurable effect on the bore-hole walls.

ity. The structures of steady shock profiles are presented and compared for both types. Finally a brief discussion is included on the simplified evolution equations for a far field transient behavior.

85-347
Simple Waves and Shock Waves Generated by an Incident Shock Wave in Two-Dimensional Hyperelastic Materials
Yongchi Li, T.C.T. Ting
Univ. of Science and Technology of China, Hefei, Anhui, China
J. Appl. Mech., Trans. ASME, 51 (3), pp 586-594 (Sept 1984), 8 figs, 14 refs

KEY WORDS: Shock waves, Wave reflection

The reflection of an oblique plane shock wave from a boundary in a two-dimensional isotropic hyperelastic material is studied. Illustrative examples are presented to show how one can determine the reflected waves from a rigid boundary. It is also shown that for certain incident shock waves, there exists only one reflected wave.

85-348
Torsional Shock Waves in a Viscoelastic Rod
N. Sugimoto, Y. Yamane, T. Kakutani
Osaka Univ., Toyonaka, Osaka 560, Japan
J. Appl. Mech., Trans. ASME, 51 (3), pp 595-601 (Sept 1984), 2 figs, 11 refs

KEY WORDS: Shock waves, Wave propagation, Rods, Viscoelastic properties

The propagation of torsional shock waves in a thin circular viscoelastic rod is investigated theoretically. An analysis is carried out based on the approximate equations previously derived. Two typical viscoelastic models are considered, which possess, respectively, the discrete and continuous relaxation spectrum. One is the usual Maxwell-Voigt model and the other is a new model whose relaxation function is given by a power law with weak singular-

85-349
Transonic Shock Interaction with a Tangentially-Injected Turbulent Boundary Layer
G.R. Inger, A. Deane
West Virginia Univ., Morgantown, VA
19 pp (Jan 1984), AD-A142 277

KEY WORDS: Shock waves, Boundary layer, Turbulence

A non-asymptotic triple deck theory of transonic shock/turbulent boundary layer interaction is described. It takes into account the influence of upstream tangential injection on a curved wall. In addition to Reynolds number and shock strength, the theory is parameterized by arbitrary values of the incoming boundary layer shape factor, wall jet maximum velocity ratio and nondimensional height of this ratio. Results of a comprehensive parametric study are then presented. It is shown that the wall jet effects significantly reduce both the streamwise scale and displacement thickening of the interaction zone.

85-350
Ground and Air Vibrations Caused by Surface Blasting. Volume 1. Executive Summary
J.J.K. Daemen, R.C. Barkley, A. Ghosh, C.R. Morlock
Arizona Univ., Tucson, AZ
Rept. No. BUMINES-OFR-105(1)-84, 121 pp (Sept 1983), PB84-191931

KEY WORDS: Air blast, Ground vibration, Prediction techniques

Ground and air vibrations induced by large surface blasts were monitored and the field results, as well as a large number of published results were used to assess the performance of existing predictors. The

development of improved prediction methods was pursued. Field monitoring was performed with four seismographs giving complete wave records at limestone quarries, coal strip mines, and an open pit copper mine. A complete blast vibration results allowing prediction of frequency content and duration as well as peak velocities.

85-351
Ground and Air Vibrations Caused by Surface Blasting. Volume 2. Ground Vibration Monitoring and Assessment of Conventional Predictors
S.A. Shoop, J.J.K. Daemen
Arizona Univ., Tucson, AZ
Rept. No. BUMINES-OFR-105(2)-84, 195 pp (Sept 1983), PB84-191949

KEY WORDS: Air blast, Ground vibration, Prediction techniques

Thirty-seven blasts were monitored using either three or four seismographs at four coal strip mines and at a limestone quarry. Statistical analysis of the data show that square root, cube root, and site specific scaling methods predict peak particle velocities with about the same degree of reliability. Some mines have peak particle velocities that are significantly lower or higher than the Bureau of Mines averages.

85-352
Ground and Air Vibrations Caused by Surface Blasting. Volume 3. Computer Simulation Predictor of Ground Vibrations Induced by Blasting
R.C. Barkley, J.J.K. Daemen
Arizona Univ., Tucson, AZ
Rept. No. BUMINES-OFR-105(3)-84, 237 pp (Sept 1983), PB84-191956

KEY WORDS: Computer programs, Air blast, Ground vibration, Prediction techniques

A computer program was written to simulate ground vibrations induced by multiple-hole surface blasts. The program is an inexpensive and relatively each to use tool for predicting the principal blast vibration characteristics that determine damage and annoyance potential. Peak particle velocity, frequency content, and pulse duration are varied. The program generates a complete ground motion history by superposing, at any surface position, the vibrations induced by each individual explosives charge.

85-353
Ground and Air Vibrations Caused by Surface Blasting. Volume 4. A New Analytical Predictor of Ground Vibrations Induced by Blasting
A. Ghosh
Arizona Univ., Tucson, AZ
Rept. No. BUMINES-OFR-105(4)-84, 316 pp (Sept 1983), PB84-191964

KEY WORDS: Air blast, Ground vibration, Prediction techniques

A new analytical formula for predicting ground vibrations induced by blasting is proposed. One factor accounts for geometrical spreading and one factor corresponds to inelastic attenuation. The geometrical spreading function is based on likely source geometries idealized as either square root, cube root, or site specific scaling and on the propagation characteristics of predominant wave types.

85-354
Ground and Air Vibrations Caused by Surface Blasting. Volume 5. Air Vibrations: Monitoring and Predictor Assessment
C.R. Morlock, J.J.K. Daemen
Arizona Univ., Tucson, Az
Rept. No. BUMINES-OFR-105(5)-84, 175 pp (Sept 1983), PB84-191972

KEY WORDS: Air blast, Ground vibration, Prediction techniques

Airblasts were monitored at four coal strip mines and at a limestone quarry. Thirty-

seven production blasts were monitored with 3 seismographs resulting in 111 complete air pressure records. Instrumentation selection and use is described. Data analysis includes an assessment of the predictability of peak overpressures by means of the cube root scaled distance law. It was found that predictability for the cases studied is not good. An extensive discussion of possible explanations is included. A detailed analysis of the frequency content of the observed airblasts, of considerable importance in evaluation potential annoyance problems, was made for all records. A computer program was written to simulate airblasts induced by multiple-hole blasts.

85-355

Methods for Predicting Rubble Motion During Blasting

J.T. Schamaun

Sandia National Labs., Albuquerque, NM

Rept. No. SAND-84-135C, CONF-840633-4, 11 pp (1984), DE84008026

KEY WORDS: Explosion effects, Blast effects

Recent applications of explosives and blasting agents to rubble rock have led to requirements for more elaborate design and analysis methods. In this paper, two analytical methods are presented which describe the large rubble motion during blasting. These methods provide the blast designer with a tool for evaluation and further refinement of blasting patterns and timing sequences.

85-356

'Do-It-Yourself' Fallout/Blast Shelter Evaluation

P.T. Nash, W.E. Baker, E.D. Esparza, P.S. Westine

Southwest Res. Inst., San Antonio, TX

Rept. NO. SWRI-7531, UCRL-15606, 182 pp (Mar 1984), AD-A141 688

KEY WORDS: Protective shelters, Blast-resistant structures

Expedient fallout shelters recommended to the general public were evaluated for their potential to provide safety to occupants during nuclear blast. Research included a literature search for expedient shelter designs and evaluations of the designs to certify their ability to protect occupants. Shelters were evaluated systematically by first analyzing each design for expected failure loads. Next, scale model tests were planned and conducted in the Fort Cronkhite shock tunnel. Structural responses and blast pressures were recorded in a series of twelve experiments involving 96 structural response models. Two igid models were included in each test to measure internal blast pressure leakage. Probabilities of survival were determined for each of the shelters tested.

VIBRATION EXCITATION

85-357

Effects of Viscosity on Transonic-Aerodynamic and Aeroelastic Characteristics of Oscillating Airfoils

P. Guruswamy, P.M. Goorjian

NASA Ames Res. Ctr., Moffett Field, CA

J. Aircraft, 21 (9), pp 700-707 (Sept 1984), 14 figs, 11 refs

KEY WORDS: Airfoils, Flutter, Aerodynamic characteristics, Computer program

Studies were made to investigate the effects of viscosity on aerodynamic and aeroelastic characteristics of oscillating airfoils. The computer code LTRAN2 (viscous), which is based on a small-disturbance aerodynamic theory, was used to make aerodynamic computations. Two viscous models, the viscous-ramp model and the lag-entrainment model, were considered. Flutter speeds were computed for airfoils studied along with the effects of viscosity on the airfoils. Results from the viscous methods show improvement over the inviscid method.

85-358

Recent Developments in the F-16 Flutter Suppression with Active Control Program

R.P. Peloubet,Jr., R.L. Haller, R.M. Bolding
General Dynamics, Fort Worth, TX
J. Aircraft, 21 (9), pp 716-721 (Sept 1984), 12 figs, 9 refs

KEY WORDS: Active flutter control

A series of wind tunnel tests of the F-16 flutter model employing active control to suppress flutter was conducted during October 1981. These tests complemented the initial series of tests conducted in February 1979. Questions associated with the validity of the measured open-loop frequency response function as a true indicator of the model's unaugmented stability with the flutter suppression system engaged were resolved by temporarily disengaging the system Tests were conducted for a simulated actuator failure. Flutter suppression was demonstrated for two external store configurations. One configuration exhibited symmetric flutter and the other exhibited antisymmetric flutter.

88-359

Identification of Time-Dependent Exciting Vectors and Their Further Processing Presented by Means of Torsional Vibrations

E.R. Koehler, S.W.P. Liebig, A. Lingener
Deutche Reichsbahn Forschungs- und Entwicklungswerk, Blankenburg, E. Germany
Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 145-150, 7 figs, 3 refs

KEY WORDS: Vibration excitation, Time-dependent excitation, Torsional excitation

Identification of non-measurable exciting vectors of mechanical systems demands information on the system characteristics and on measured vibrations at an accessible point of the system. This paper deals with the data processing required.

85-360

Cavitation in an Oscillatory Oil Squeeze Film

D.W. Parkins, R. May-Miller
Cranfield Inst. of Technology, Cranfield, MK430AL, UK
J. Tribology, Trans. ASME, 106 (3), pp 360-367 (July 1984), 12 figs, 10 refs

KEY WORDS: Squeeze-film bearings, Cavitation, Experimental data

This paper records observed features of cavitation arising in an oscillatory oil squeeze film. In the experimental apparatus, two nondeformable surfaces contained the oil film. The paper contains photographs of cavitation bubble patterns at important points in the typical oscillatory cycles together with their location in the oil film pressure and thickness time histories.

85-361

The Acoustic Field on the Surface of Circular Radiators at High Frequencies (Das Schallfeld auf der Oberflache von Kreisstrahlern bei hohen Frequenzen)

H. Fleischer
Institut fur Mechanik, Fachbereich Luft- und Raumfahrttechnik, Hochschule der Bundeswehr, Munchen, Fed. Rep. Germany
Acustica, 55 (5), pp 268-276 (Aug 1984), 7 figs, 11 refs (In German)

KEY WORDS: Circular bars, Mode shapes, Acoustic excitation

The local distribution of the acoustic pressure on the surface of circular structures vibrating in an infinitely large baffle is calculated. A simple rule is derived from this observation for the calculation of acoustic power radiated at high frequencies, based on the mean square of mechanical velocity.

85-362

Aerodynamic Characteristics of a Two-Dimensional Moving Spoiler in Subsonic and Transonic Flow

H. Consigny, A. Gravelle, R. Molinaro
Office National d'Etudes et de Recherches Aerospatiales, Chatillon Cedex, France
J. Aircraft, 21 (9), pp 687-693 (Sept 1984), 15 figs, 9 refs

KEY WORDS: Aerodynamic characteristics, Spoilers

An experimental study has been conducted in two-dimensional flow to determine the steady and unsteady performances of a spoilerlike control surface. Results were obtained with a spoiler performing simple harmonic oscillations. These show unsteady (first harmonic) pressure distributions and aerodynamic coefficients which strongly depend on freestream Mach number, spoiler mean deflection, and frequency of oscillations. Typical transient pressures and transient loads recorded for a sudden and large change in spoiler angle indicate that large unsteady, and significant nonlinear effects are generated by the motion of this type of control. The possibility of a reversal of the control effectiveness is also demonstrated.

85-363
The Use of Multipoles for Calculating the Aerodynamic Interference Between Bodies of Revolution
P.A.T. Christopher, C.T. Shaw
Cranfield Inst. of Technology, Cranfield, UK
J. Aircraft, 21 (9), pp 673-679 (Sept 1984), 14 figs, 10 refs

KEY WORDS: Bodies of revolution, Wing stores, Aerodynamic loads

A method is presented which uses the higher-order solutions of Laplace's equation to generate the flows between bodies of revolution which have complicated mutual aerodynamic interference. Such a situation commonly exists when several aircraft stores are grouped together under an aircraft. The method is shown to be a consistent approximation to the surface source methods, and gives good results for bodies with smooth meridian profiles.

85-364
Dynamics of a Near-Resonant Fluid-Filled Gyroscope
R.F. Gans
U.S. Army Ballistic Res. Lab., Aberdeen Proving Ground, MD
AIAA J., 22 (10), pp 1465-1471 (Oct 1984), 8 figs, 9 refs

KEY WORDS: Fluid-filled containers, Gyroscopes

The behavior of a fluid-filled gyroscope having a natural coning frequency near that of the inertial oscillation of a contained rotating liquid is calculated. The theory is compared to observations from the literature to assess the limitations of the theory. Some comparison with earlier work is given. It is concluded that the present theory reflects the data reasonably well and that is is an improvement over previous work.

MECHANICAL PROPERTIES

DAMPING

85-365
Equivalent Stiffness and Damping Coefficients for Squeeze Film Dampers
E.J. Hahn
The Univ. of New South Wales, Australia
Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 507-514, 6 figs, 7 refs

KEY WORDS: Squeeze film dampers, Stiffness coefficients, Damping coefficients

Analyses of multi-degree of freedom rotor-bearing systems incorporating nonlinear elements, such as squeeze film dampers, generally necessitate time-consuming transient solution. Consequently, it is often too expensive to carry out parametric de-

sign studies on such systems. A general technique is given for linearizing the nonlinear element forces using equivalent stiffness and damping coefficients based on energy dissipation and energy storage-release concepts. The approach is illustrated and tested for both centrally preloaded squeeze film dampers and for squeeze film dampers. The results predicted by using such equivalent stiffness and damping coefficients agree quite well with those obtained from the full transient solution. An iterative procedure is proposed which, with the aid of such stiffness and damping coefficients, should significantly reduce the computation time presently needed.

85-366

Generalized Criteria for the Evaluation of Torsional Vibration Dampers

K. Federn

Technische Universitat, Berlin

Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 127-137, 19 figs, 39 refs

KEY WORDS: Dampers, Torsional vibration

Necessity and new trends for increasing the damping capacity per unit volume of torsional vibration dampers are illustrated by sketches.. The ways of modelling the engine's drive system (flywheel, crankshaft, damper) for programmed calculation are described. Evaluation and optimization of the modal-system's substructure "damper" are made most efficiently by the help of diagrams in which the ring-inertia and mode-frequency are related.

85-367

Dual Clearance Squeeze Film Damper for High Load Conditions

D.P. Fleming

NASA Lewis Res. Ctr., Cleveland. OH

Rept. No. E-2053, NASA-TM-83619, 14 pp (1984), N84-25064

KEY WORDS: Squeeze film dampers, Aircraft engines, Vibration control, Turbine engines, Blade loss dynamics

Squeeze film dampers are widely used to control vibrations in aircraft turbine engines and other rotating machinery. However, if shaft unbalance rises appreciably above the design value a conventional squeeze film becomes overloaded. It is no longer effective in controlling vibration amplitudes and bearing forces. A damper concept characterized by two oil films is described. Under normal conditions, only one low-clearance film is active, allowing precise location of the shaft centerline. Under high unbalance conditions, both films are active, controlling shaft vibration in a near-optimum manner.

85-368

Application of the Internal Friction Damping Nondestructive Evaluation(IFD-NDE) Technique for Liquefied Natural Gas (LNG) Tanks

R.W. Weinreich, A.A. Hochrein, Jr., A.P. Thiruvengadam

Daedalean Associates, Inc., Woodbine, MD

Rept. No. RSW-8019-001-TR, MA-RD-770-83069, 111 pp (Jan 1984), PB84-202118

KEY WORDS: Coulomb friction, Internal damping, Nondestructive tests, Tanks (containers), Gases

A nondestructive test technique has been identified which has the potential for being an inspection tool for surveying shipboard liquefied natural gas (LNG) tanks. The technique is called internal friction damping nondestructive evaluation. The physical property that is monitored in this technique is the rate at which an energy impulse imparted to a material or structure decays due to the internal friction of the material. This report details the application of this technique from laboratory testing of bar specimens to testing of field structures analogous to LNG tanks.

85-369

Constant Force Friction Damper

G.E. Campbell
NASA Lyndon B. Johnson Space Ctr., Houston, TX
PAT-APPL-6-519 660, 9 pp (Feb 8, 1983)

KEY WORDS: Dampers, Coulomb friction, Space shuttles

A friction type damper unit has opposed conical wedge rings, on a wedge bolt plunger extending axially into a barrel connected to the body of a space vehicle, as in the payload bay of the space shuttle orbiter. The plunger is connected to the softly sprung payload, as the inertial upper stage (IUS) in the payload bay of the vehicle. Friction shoes are slideable on the barrel and expandable by the wedge rings. The wedge rings are connected to the plunger through opposed balanced stacks of Belleville washers which provide the required high spring constant and balanced reversing forces.

85-370
Response of an Oscillator to a Ground Motion with Coulomb Friction Slippage
R. Parnes
Tel-Aviv Univ., 69978 Tel-Aviv, Israel
J. Sound Vib., 94 (4), pp 469-482 (June 22, 1984), 12 figs, 11 refs

KEY WORDS: Soil-structure interaction, Coulomb friction, Ground motion

The response of an oscillator to a time-harmonic ground motion excitation is studied. The resulting interacting force between the surrounding ground and oscillator is assumed to follow the laws of Coulomb friction. Time histories of the displacement and interaction force are obtained for various values of the two governing parameter of the system.

85-371
A Performance Comparison of Vibration Damping Materials
W.J. Hanson, G.A. Hampel
Liberty Mutual Res. Ctr., Hopkinton, MA
S/V, Sound Vib., 18 (7), pp 22-23 (July 1984), 52 figs, 3 tables, 32 refs

KEY WORDS: Material damping, Polymers

This article reports on the vibration damping properties of 46 commercial polymeric damping materials. The evaluation of these materials covers the temperature and frequency ranges encountered in most industrial environments. The data will enable the potential user of these damping materials to make direct comparisons of various products.

FATIGUE

85-372
Maximax Response and Fatigue Damage Spectra - Part 1
C. Lalanne
French Atomic Energy Commission
J. Environ. Sci., 27 (4), pp 35-40 (July/Aug 1984), 5 figs, 9 refs

KEY WORDS: Fatigue life, Materials

In this paper, the criteria of extreme-response spectra and of fatigue-damage spectra are defined. The severity of several vibrations or shocks are compared.

85-373
Fatigue Crack Growth in Large Specimens with Various Stress Ratio
F. Ellyin, H.-P. Li
The Univ. of Alberta, Edmonton, Alberta, Canada
J. Pressure Vessel Tech., Trans. ASME, 106 (3). pp 255-260 (Aug 1984), 8 figs, 15 refs

KEY WORDS: Fatigue life, Crack propagation, Steel

An experimental investigation has been carried out on large plates made of pressure vessel steel A516 Gr.70, to determine

the fatigue crack growth rate. The results are also compared with the recommended ASME Code formula and are found to be in fairly good agreement.

85-374

Applications of the Scanning Electron Microscope to Concrete Failure (Axial, Biaxial, and Dynamic)

K. Derucher
Stevens Inst. of Tech., Hoboken, NJ
Rept. No. AFOSR-TR-84-431, 101 pp (Mar 5, 1984), AD-A141 788

KEY WORDS: Fatigue life, Crack propagation

The major objective was to directly observe the formation and/or propagation of microcracks in concrete (plain and reinforced) both before and after applications of axial, biaxial, and dynamic stress fields. As part of this objective, procedures, techniques, apparatus, and equipment were developed and/or modified for the study of concrete fracture utilizing the scanning electron microscope.

85-375

On the Mechanics of Fatigue Crack Growth Due to Contact Loading

G.R. Miller
Ph.D. Thesis, Northwestern Univ., 58 pp (1984), DA8411170

KEY WORDS: Fatigue life, Crack propagation

This dissertation presents and discusses the results of an analysis of the propagation behavior of fatigue cracks due to contact loading. Stress intensity factors are computed for a surface breaking crack in the presence of a near surface inclusion, and under the influence of interacting asperities at the surface.

85-376

Near-Threshold Fatigue Crack Propagation: A Perspective on the Role of Crack Closure

S. Suresh, R.O. Ritchie
Brown Univ., Providence, RI
Rept. No. LBL-16263, CONF8310268-1, 76 pp (Nov 1983),
DE84009669

KEY WORDS: Fatigue life, Crack propagation

In recent years, mechanistic and continuum studies on fatigue crack propagation, particularly at near-threshold levels, have highlighted a dominant role of crack closure in influencing growth rate behavior. In this paper the various sources of closure induced by cyclic plasticity, corrosion deposits, irregular fracture morphologies, viscous fluids and metallurgical phase transformations are reviewed and modeled. Many of the commonly observed effects of mechanical factors (load ratio, microstructural factors and certain environmental conditions) can be traced to the extrinsic influence of closure in modifying effective driving force for crack extension. The implications of such closure mechanisms are discussed in the light of constant and variable amplitude fatigue behavior.

85-377

Improved Damage-Tolerance Analysis Methodology

J.B. Chang, R.M. Engle
Rockwell International, Los Angeles, CA
J. Aircraft, 21 (9), pp 722-730 (Sept 1984), 8 figs, 4 tables, 24 refs

KEY WORDS: Fatigue life, Aircraft, Metals, Prediction techniques

Computerized damage-tolerance analysis methodology, which can be used to predict fatigue crack growth behavior and lives of various types of cracks contained in metallic structures, subjected to complex spectrum loadings, has been developed.de This analysis method was developed primarily for the performance of the damage-tolerance analysis in the detail design stage of

any aircraft system. Results demonstrated this damage-tolerance analysis methodology provides reliable predictions on fatigue crack growth lives for cracked specimens subjected to spectrum loadings of various classes of aircraft.

85-378
RMS Fatigue Curves for Random Vibrations
B. Brenneman, J.Q. Talley
Babcock & Wilcox Co., Lynchburg, VA
ASME Paper No. 84-PVP-60

KEY WORDS: Fatigue life, Random vibration

Through the method described in this paper, RMS fatigue curves corresponding to the ASME fatigue curves are derived and presented. These curves provide a straightforward method of accurately and easily solving random vibration fatigue problems.

85-379
On-Line Fatigue Life Predictions of Steel Specimens Under Stochastic Loading by Time Series Modeling of the Output
B.D. Notohardjono, D.S. Ermer
Univ. of Wisconsin, Madison, WI
ASME Paper No. 84-PVP-78

KEY WORDS: Fatigue life, Prediction techniques, Steel

This new approach can be used for on-line prediction of a potential fatigue failure. Several illustrations demonstrating its application and accuracy are given.

85-380
Corrosion Fatigue of Steel Under Cavitation Erosion Generated Intermittently in 3% Salt Water (Results of Two-Stage Tests with and Without Cavitation Erosion)
T. Okada, Y. Iwai, S. Hattori
Fukui Univ., Bunkyo 3-9-1, Fukui, Japan
Wear, 26 (1), pp 85-98 (June 1, 1984), 14 figs, 6 tables, 6 refs

KEY WORDS: Fatigue tests, Corrosion fatigue, Underwater structures, Steel

Two-stage fatigue tests with and without cavitation erosion were performed in 3% salt water. When corrosion fatigue with cavitation erosion (erosion fatigue) is changed to corrosion fatigue during a test, the fatigue life decreases remarkably. The total number of stress cycles to failure becomes smaller than that for tests involving erosion fatigue only.

85-381
The Influence of Coldforming on the Low Cycle Fatigue Behaviour of the Fine-Grained Structural Steel Fe E 47 and the Age-Hardened Aluminium Alloy AlCuMg2
C.M. Sonsino
Fraunhofer-Institut fur Betriebsfestigkeit (LBF), Bartningstrasse 47, 6100 Darmstadt, Fed. Rep. Germany
Intl. J. Fatigue, 6 (3), pp 173-183 (July 1984)

KEY WORDS: Fatigue tests, Steel, Aluminum, Alloys

Fatigue tests were carried out under strain and load control on the cyclically softening structural steel Fe E 47 and on the cyclically hardening aluminium alloy AlCuMg2. The crack initiation period of both materials decreased with increasing degree of coldforming. This reduction in fatigue life is explained by the Bauschinger effect. The Bauschinger effect was introduced into fatigue life calculation by considering monotonic stress/strain curves in tension and compression for different degrees of coldforming and by introducing a damage parameter.

ELASTICITY AND PLASTICITY

85-382
Determination of Failure Characteristics of Materials and Structures

H. Liebowitz
George Washington Univ., Washington, D.C.
36 pp (Nov 20, 1983), AD-A142 310

KEY WORDS: Failure analysis

A research program has been pursued with the objective of examining failure characteristics of materials and structures analytically and experimentally. The expression for the nonlinear energy toughness was rederived for a generalized instability condition and new expressions were derived for biaxial loading situations. The geometry dependence of the nonlinear energy toughness was studied experimentally using center-cracked thin sheet specimens and thicker compact tension specimens of several alloys. This was compared with other nonlinear toughness parameters.

85-383

Dynamic Shakedown of Elastic-Plastic Solids for a Set of Alternative Loading Histories

C. Polizzotto
Istituto di Scienza delle Costruzioni, Facolta di Ingegneria, Universita di Palermo, Viale delle Scienze, I-90128 Palermo, Italy
Intl. J. Nonlin. Mech., 19 (4), pp 363-371 (1984), 15 refs

KEY WORDS: Shakedown theorem, Elastic plastic properties

This paper deals with dynamic shakedown of an elastic-perfectly plastic solid body subjected to a loading history which is unknown but is allowed to belong to a given set of loading histories. A sufficient shakedown theorem is given and a bounding principle for the plastic work produced is formulated in terms of the dynamic elastic responses to a discrete set of loading histories. The solution of a minimization problem gives the most stringent bound which also proves to possess a local character, i.e., it regards the plastic work density at any point.

WAVE PROPAGATION

85-384

Diffraction of Elastic Waves by a Sub-Surface Crack (Anti-Plane Motion)

F.L. Neerhoff, J.H.M.T. van der Huden
Univ. of Technology, Delft, The Netherlands
J. Sound Vib., 93 (4), pp 523-536 (Apr 22, 1984), 13 figs, 9 refs

KEY WORDS: Elastic waves, Wave diffraction, Cracked media

A rigorous theory of the diffraction of SH-waves by a stress-free crack embedded in a semi-infinite elastic medium is presented. The incident time-harmonic SH-wave is taken to be either a uniform plane wave or a cylindrical wave originating from a surface line-source. The resulting boundary-value problem for the unknown jump in the particle displacement across the crack is solved by employing an integral equation approach. The unknown quantity is expanded in a complete sequence of Chebyshev polynomials.

85-385

On Wave Modes with Zero Group Velocity in an Elastic Layer

J.L. Tassoulas, T.R. Akylas
The Univ. of Texas at Austin, Austin, TX 78712
J. Appl. Mech., Trans. ASME, 51 (3), pp 652-656 (Sept 1984), 4 figs, 10 refs

KEY WORDS: Wave propagation, Layered materials, Elastic properties, Natural frequencies, Circular plates

A study is made of time-harmonic wave modes in an elastic layer in plane strain with traction-free surfaces. At points of the Rayleigh-Lamb frequency spectrum where the group velocity vanishes, there exist nonseparable time-harmonic modes in which the amplitudes of the displacements vary linearly in the direction along the layer. These modes are used to explain the terrace-like structure of the free-vi-

bration frequency spectrum of a circular disk.

85-386
On the Nonlocal Theory of Wave Propagation in Elastic Plates
J.L. Nowinski
Univ. of Delaware, Newark, DE 19716
J. Appl. Mech., Trans. ASME, 51 (3), pp 608-613 (Sept 1984), 1 fig, 1 table, 44 refs

KEY WORDS: Wave propagation, Plates, Elastic properties, Continuum mechanics

Propagation of longitudinal waves in isotropic homogeneous elastic plates is studied in the context of the linear theory of nonlocal continuum mechanics. The dispersion equation obtained for the plane longitudinal waves in an infinite medium is matched with the parallel equation derived in the theory of atomic lattice dynamics. Using the integroalgebraic representation of the stress tensor and the Fourier transform, the system of two coupled differential field equations is solved giving the frequency equations for the symmetric and antisymmetric wave modes. It is found that the short wave speed in the Poisson medium differs by about 13 percent from the speed established in the classical theory. A numerical example is given.

85-387
Finite Element Eigenfunction Method (FEEM) for Elastic Wave Scattering by Arbitrary Three-Dimensional Axisymmetric Scatterers
J.H. Su, V.V. Varadan, V.K. Varadan
The Ohio State Univ., Columbus, OH 43210
J. Appl. Mech., Trans. ASME, 51 (3), pp 614-621 (Sept 1984), 12 figs, 16 refs

KEY WORDS: Wave scattering, Elastic waves, Finite element technique

A finite element eigenfunction method is formulated for elastic wave scattering by bounded three-dimensional axisymmetric regions (cavity, homogeneous, or inhomogeneous) for harmonic waves incident at arbitrary angles. The solutions are hence three-dimensional and no longer axisymmetric. The scattering region is enclosed within a sphere. The scattered field outside the sphere is expanded in outgoing vector spherical functions.

85-388
Scattering of Elastic Waves by a Plane Crack of Finite Width
J.H.M.T. van der Hijden, F.L. Neerhoff
Schlumberger-Doll Research, Ridgefield, CT 06877
J. Appl. Mech., Trans. ASME, 51 (3), pp 646-651 (Sept 1984), 8 figs, 17 refs

KEY WORDS: Elastic waves, Wave scattering, Cracked media

A rigorous theory of the diffraction of time-harmonic elastic waves by a cylindrical, stress-free crack embedded in an elastic medium is presented. The incident wave is taken to be either a P-wave or an SV-wave. The resulting boundary-layer problem for the unknown jump in the particle displacement across the crack is solved by employing an integral-equation approach. The jump is expanded in a complete sequence of Chebyshev polynomials, and, writing the Green's function as a Fourier integral, a system of algebraic equations is obtained. Numerical results are presented in the form of dynamic stress intensity factors, scattering cross sections, and normalized power-scattering characteristics. Some of them deviate from earlier published results.

EXPERIMENTATION

MEASUREMENT AND ANALYSIS

85-389
Selection of Degrees of Freedom for Dynamic Analysis

K. Matta
General Dynamics, Groton, CT
ASME Paper No. 84-PVP-61

KEY WORDS: Component mode synthesis

A technique for the selection of dynamic degrees of freedom of large, complex structures for dynamic analysis is described and the formulation of Ritz basis vectors for component mode synthesis is presented. The technique can be used to select the DDOF to reduce the size of large eigenproblems and to select the DDOF to eliminate the singularities of the assembled eigenvalue problem of components mode synthesis.

85-390

The Improved Frequency Response Function and its Effect on Modal Circle Fits

K.B. Elliott, L.D. Mitchell
Virginia Polytechnic Inst. and State Univ., Blacksburg, VA 24061
J. Appl. Mech., Trans. ASME, 51 (3), pp 657-663 (Sept 1984), 11 figs, 2 tables, 7 refs

KEY WORDS: Frequency response function, Curve fitting, Modal analysis

When structures are excited by random force excitation the circle fits of the data around resonance are usually poor. The structural parameter estimates, which results from this fit, are usually erroneous. No matter how elegant the circle or the multimodal fit, the results will be poor if the frequency response function is a poor representation of the actual structural response. In general for the random excitation case, this is the case. Thus, the proposed method eliminates long-standing system analysis errors through the use of a simple revision of the way the data are treated in the FFT processor around the resonance regions.

85-391

Research on Modal Analysis (1st Report, General Purpose Program of Curve Fitting and Basic Study)

M. Nagaike, A. Nagamatsu
Tokyo Inst. of Technology, 12-1, Ohokayama 2-chome, Meguro-ku, Tokyo, 152, Japan
Bull. JSME, 27 (229), pp 1544-1548 (July 1984), 8 figs, 3 refs

KEY WORDS: Modal analysis, Curve fitting, Frequency domain method, Time domain method, Damping effects

A system program of curve-fitting to analyze the modal parameters from a transfer function obtained by a vibration test and to reconstruct the frequency curve of the transfer function is described. Both the frequency domain and the time domain curve-fittings are possible under the assumption of three kinds of dampings, namely proportional viscous, general viscous and hysteretic dampings. A transfer function of a mass-spring system of three degrees of freedom is fitted by six methods using this program. The calculated results of modal parameters are compared with rigorous solutions. A transfer function of a steel plate obtained by the vibration test is fitted using this program; the result is compared with the experimental one.

85-392

Deflection of Drives; Experimental Modal Analysis, Comparison of Calculation with Measurement (Nachgiebigkeitsverhalten von Antriebsstrukturen; experimentelle Modalanalyse, Vergleich Rechnung - Messung)

H. Summer
Industrie Anzeiger, 106 (57), pp 36-37 (July 7, 1984) (In German)

KEY WORDS: Rotors, Drives, Experimental modal analysis

A drive structure, which had been earlier analyzed statically and dynamically by means of a Torsion-FEM Program, is subjected to an experimental modal analysis with the usual restraints. The necessary prestress, the effect of nonlinearities, and the recalculation of the measured translations and rotations is addressed. Notwithstanding the restraints, the calculated weak

spots are confirmed; the spring-normalized eigenvectors are compared for the detection of modeling errors.

expressed by strains. The measurement technique with strain gauges is developed to identify more modal parameters and is also applicable to various excitations.

85-393
Multi-Shaker Random Model Testing
A.M. Kabe
Aerospace Corp., El Segundo, CA
Rept. No. TR-84 (4429-1)-1, SD-TR-84-11, 38 pp (Jan 30, 1984), AD-A142 094

KEY WORDS: Shakers, Test facilities, Experimental modal analysis

A mode survey test procedure that combines multi-shaker correlated broadband random excitation of the test artricle with the mode isolation features of multiple shaker excitation is described. The procedure takes advantage of multiple shaker excitation to best isolate the target mode response from all other modes. Mode parameters are then established from direct observation of frequency response functions.

85-394
Vibration Modal Analysis by Means of Impulse Excitation and Measurement Using Strain Gauges
L.Y. Yi, F.R. Kong, Y.S. Chang
Nanjing Aeronautical Inst., Nanjing, People's Rep. of China
Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 391-396, 7 figs, 3 tables, 8 refs

KEY WORDS: Experimental modal analysis, Impulse testing, Strain gages, Parameter identification technique

A modal analysis of vibrational systems by means of impulse excitation, strain gauging and nonlinear optimal identification is described in this paper. Also described are the concept of strain mobility, the strain displacement relationships, and the derivation of the formulae of transfer functions

85-395
Analysis of Vibration by Substructure Synthesis Method (Part 3, Application to Diesel Generator Package)
A. Nagamatsu, Y. Fujita, T. Ikeuchi, M. Shirai
Tokyo Inst. of Technology, 12-1, Ohokayama 2-chome, Meguro-ku, Tokyo, Japan
Bull. JSME, 27 (229), pp 1487-1492 (July 1984) 21 figs, 6 tables, 5 refs

KEY WORDS: Substructuring methods, Building block approach, Diesel engines, Generators

The vibration of a diesel generator package is analyzed by the substructure synthesis method, namely the building block approach. The diesel generator package is divided into three substructure, namely a generator, a common plate and a diesel engine. The transfer function of each substructure is measured by a vibration test under the free condition. The transfer functions of all substructures are combined to make an equation of motion for the total structure. The analyses are performed for both a model and an actual machine, and the results are compared with experimental ones.

85-396
Measurement of Nonlinear Vibration by Signal Compression Method
N. Aoshima
Univ. of Tsukuba, Sakura-mura, Ibaraki-ken 305, Japan
J. Acoust. Soc. Amer., 76 (3), pp 794-801 (Sept 1984) 17 figs, 2 refs

KEY WORDS: Signal compression method, Wave propagation, Vibration measurement, Signal processing techniques

The signal compression method is shown to be useful for analyzing nonlinear systems as well as linear systems. If a nonlinear system can be modeled as a parallel combination of a linear part and elements subject to a power law, such as a squarer, they can be analyzed separately by the signal compression method. A test signal of the signal compression method has been generated by an expanding filter. The linear response can be detected by a compression filter. Then the nonlinear component generated by the squarer is also compressed by another second-order compression filter. The frequency tripled component, which is generated by a third power nonlinear element, is compressed by the third-order compression filter. Results of model experiments by an analog squarer and a numerical nonlinear processing are exemplified together with nonlinear effects observed in a floor vibration experiment.

85-397

Time Domain Testing of Surface Acoustic Wave Filters

G. Albrecht, W. Faber, G. Tobolka
Siemens AG, Werksbereich Passive Bauelemente, Munich, W. Germany
Siemens Res. Dev. Repts., 13 (4), pp 171-175 (1984) 10 figs, 4 refs

KEY WORDS: Acoustic filters, Time domain method, Transducers

A computer-controlled time domain transmission test setup has been expanded to allow the measurement of reflection coefficients. The time domain response of SAW filters is measured for both transmission and reflection coefficients. Theoretical curves computed following the measuring procedure show satisfactory agreement with the measured curves. The test setup is used to find a non-apodized transducer that is particularly suitable for the given application. A SAW filter realized with this transducer will satisfy the requirements.

85-398

Smoothed Frequency Responses for Matrix-Characterized Vibrating Structures

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J. Sound Vib., 93 (2), pp 249-271 (Mar 22, 1984) 7 figs, 13 refs

KEY WORDS: Frequency response

A method for predicting smoothed frequency responses for matrix-characterized structures is shown to be practical. Smoothed frequency responses are the same as conventional responses for real mobility versus frequency, except for the removal of resonant-antiresonant detail consisting of peaks and notches. The present connection between modal density and the smoothed real mobilities is a matrix formulation of a known result. This introduces a treatment of modal density as the smoothed product of an orthogonal polynomial fit (rather than an average taken over bands of modes, such as used in Statistical Energy Analysis).

85-399

The Application of Cepstral Techniques to the Measurement of Transfer Functions and Acoustical Reflection Coefficients

J.S. Bolton, E. Gold
Univ. of Southampton, Southampton S09 5NH, UK
J. Sound Vib., 93 (2), pp 217-233 (Mar 22, 1984) 11 figs, 21 refs

KEY WORDS: Cepstrum analysis, Impulse response, Sound waves, Wave reflection, Transfer functions

Cepstral processing techniques in principle allow the separation of superposed pulses, such as those which occur in acoustic reflection, where a reflected pulse is a delayed and distorted version of the incident pulse. Additionally, the impulse response of the reflecting system, or equivalently its reflection coefficient, can also be determined. Experiments conducted on an electrical analogue of the acoustical reflection process have allowed the cepstral technique to be developed and evaluated. Good agreement is obtained between theoretical and measured transfer functions for a variety of filter networks.

85-400

Experimental Observations of the Dependence of Impedance Tube Behavior Upon Gas Phase Losses and Propellant Self-Noise

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Georgia Inst. of Technology, Atlanta, GA 30332

J. Sound Vib., 93 (2), pp 201-216 (Mar 22, 1984) 13 figs, 10 refs

KEY WORDS: Mechanical admittance, Solid propellants

Some of the unexpected behavior observed during admittance measurement of burning solid propellants in a modified impedance tube set-up is discussed. Specifically, repeated tests conducted with the same solid propellant resulted, unexpectedly, in different standing wave structures in the impedance tube when the exhaust configuration was changed. This resulted in the calculation of different admittances at the propellant surface. Observed experimental trends can be explained when the presence of gas phase damping and a propellant self-noise are taken into consideration in the development of a simplified analytical model describing behavior of the impedance tube.

85-401

The Prerequisites for Measuring Mobility with Annular Transducer Accessories

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J. Sound Vib., 94 (4), pp 495-523 (June 22, 1984) 24 figs, 20 refs

KEY WORDS: Mobility method, Transducers

The prerequisites for measuring mobility with annularly shaped devices have been investigated theoretically as well as experimentally. It is found that such a device, where a motion transducer is attached directly on to the measuring object and the excitation is applied around this transducer, constitutes a valuable piece of equipment in a variety of measurement situations. From a mobility analogy a correction function, with respect to the influence of the characteristics of the device, is derived. The simple correction function is easily implemented in a signal processing routine. The annular device, which should be useful for both stationary and transient excitation signals, also can be useful in power flow measurements.

85-402

Optimum Method of Generating Pulse Trains Corresponding to the Random Excitation Motions Based on Structural Response (Method by Means of the Evaluation of Response Spectra)

K. Suzuki, A. Sone
Tokyo Metropolitan Univ., 2-1-1 Fukazawa Setagaya-ku, Tokyo, Japan

Bull. JSME, 27 (229), pp 1549-1554 (July 1984) 14 figs, 5 refs

KEY WORDS: Pulse testing techniques, Random excitation, Dynamic structural analysis, Optimization

A generation method of appropriate pulse trains which should be utilized as alternative excitation inputs for the structural response analysis in terms of various types of random excitation is presented. Criteria for getting optimum pulse trains are established based on the evaluation of the structural response spectra. Optimization can be successfully carried out by taking artificially simulated narrowband excitations and nonstationary broadband excitations like seismic motions as inputs for numerical examples.

85-403

Installation Noise Measurements of Model SR and CR Propellers

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Rept. No. NASA-TM-85790, 103 pp (May 1984) N84-25425

KEY WORDS: Propellers, Noise measurement

Noise measurements on a 0.1 scale SR-2 propeller in a single and counter rotation

mode, in a pusher and tractor configuration, and operating at non-zero angles of attack are summarized. A measurement scheme which permitted 143 measurements of each of these configurations in the Langley 4- by 7-meter low speed tunnel is also described.

DYNAMIC TESTS

85-404
Instrumenting and Interpreting the Time-Varying Response of Structural Systems
P.L. Walter
Sandia National Labs., Albuquerque, NM
Rept. No. SAND-83-1766C, CONF-8406-101-1, 23 pp (1984) (Pres. at the Intl. Congress on Experimental Mechanics, Montreal, Quebec, Canada, June 10, 1984)
DE84009067

KEY WORDS: Testing techniques, Instrumentation, Structural response, Transducers

The dynamic testing performed on structural systems sometimes lacks specific objectives. In addition, the design of the measurement system intended to record the resultant data often does not receive adequate attention. This article presents the rationale for performing dynamic testing and provides insight for selecting transducers and determining their mounting locations to measure the resultant structural motion. Response measurements from transducers mounted on a freely-suspended bar structure are illustrated and explained. These results are generalized to more complex structures comprised of rod, plate, bar, and shell elements of varying geometries, boundary conditions, and materials.

85-405
A Method for Correlating Severity of Different Seismic Qualification Tests
D.D. Kana, D.J. Pomerening
Southwest Res. Inst., San Antonio, TX
ASME Paper No. 84-PVP-62

KEY WORDS: Seismic tests, Testing techniques

A general methodology has been developed for correlating the severity of several seismic qualification motions that may have very different dynamic characteristics. The approach, based on a vibrational equivalence concept, allows a damage comparison between two different motions to be made.

85-406
Lewis Research Center Spin Rig and Its Use in Vibration Analysis of Rotating Systems
G.V. Brown, R.E. Kielb, E.H. Meyn, R.E. Morris
NASA Lewis Res. Ctr., Cleveland, OH
Rept. No. E-1829, NASA-TP-2304, 19 pp (May 1984) N84-24578

KEY WORDS: Test facilities, Vibration tests, Shafts, Rotor blades (turbomachinery)

The Lewis Research Center spin rig was constructed to provide experimental evaluation of analysis methods developed under the NASA Engine Structural Dynamics Program. Rotors up to 51 cm (20 in.) in diameter can be spun to 16,000 rpm in vacuum by an air motor. Vibration forcing functions are provided by shakers that apply oscillatory axial forces or transverse moments to the shaft, by a natural whirling of the shaft, and by an air jet. Blade vibration is detected by strain gages and optical blade-tip motion sensors. A variety of analogy and digital processing equipment is used to display and analyze the signals. Results obtained from two rotors are discussed. A 56-blade compressor disk was used to check proper operation of the entire spin rig system. A special two-blade rotor was designed and used to hold flat and twisted plates at various setting and sweep angles. Accurate Southwell coefficients have been obtained for several modes of a flat plate oriented parallel to the plane of rotation.

85-407
Transonic Wind Tunnel Wall Interference Minimization

J.L. Grunnet
FluiDyne Engrg. Corp., Minneapolis, MN
J. Aircraft, 21 (9), pp 694-699 (Sept 1984)
12 figs, 18 refs

KEY WORDS: Aircraft, Aerodynamic characteristics, Wind tunnel tests

Obtaining accurate predictions of aircraft aerodynamic coefficients from wind tunnel tests is a difficult task. Wind tunnel users have struggled with the effects of wall interference, model support interference, subscale Reynolds number, etc., for almost the entire history of powered flight. Since wall interference is one of the principal problems, this paper emphasizes the need to minimize it, especially in the near-sonic test regime. Practical ways of minimizing wall interference are identified. This is the best accomplished for near-sonic testing by locally variable porosity with inclined hole perforations. A number of porosity setting schemes are identified, some of which are quite simple.

DIAGNOSTICS

85-408
A Review of Rolling Element Bearing Health Monitoring (III): Preliminary Test Results on Eddy Current Proximity Transducer Technique
P.Y. Kim
National Res. Council, Ottawa, Canada
Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 119-125, 12 figs, 11 refs

KEY WORDS: Monitoring techniques, Diagnostic techniques, Rotating machinery, Rolling element bearings, Eddy current probes

A new concept of using displacement transducers for rotating machinery health monitoring is discussed. An effective diagnostic method of outer and inner race damage is described. How to predict the exact angular location of the damage spot is illustrated and confirmed by experimental results. The failure detection rate in the laboratory test environment at NRC Canada, so far, has been 100%. However, the method does have difficulties in installation.

BALANCING

85-409
Insights from Applied Field Balancing of Turbomachinery
R.G. Kirk
Ingersoll-Rand Co., Phillipsburg, NJ
Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 397-407, 12 figs, 7 refs

KEY WORDS: Single-plane balancing, Turbomachinery

A review of several field balancing applications for turbomachinery is given with insights and recommendations for future *considerations.* An interesting situation is given wherein a single plane balance correction was made to get a rotor to within acceptable velocity readings while it was being balanced in a high speed balance bunker. Suggested guidelines for acceptable vibration level determination for vertically mounted motor drives are discussed in connection with a field balance for a 2983 kw (4000 horsepower) motor drive.

85-410
Computer Aided Balancing System for Mass-Produced Turbo-Rotors
K. Nishimoto, S. Morii, A. Tanba, H. Ohsawa
Mitsubishi Heavy Industries Limited, Hiroshima Technical Inst., Japan
Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 409-418, 9 figs, 1 table, 6 refs

KEY WORDS: Balancing machines, Computer-aided techniques, Turbine components, Rotors

Along with the recent progress in computer technology, various computer-aided balancing systems for rotating machinery have been developed. This paper describes a computer-aided balancing system and its features for mass-produced turbo-rotors developed by MHI.

85-411

Theory on Balancing of a Flexible Rotor by Driving Torque Excitation

K. Ono
Dept. of Mech. Engrg., Tokyo Inst. of Technology, Japan

Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 475-480, 1 fig, 7 refs

KEY WORDS: Balancing techniques, Flexible rotors, Torsional excitation

As a contribution to development of a simple and economical balancing technique, this paper presents a theoretical explanation of a novel balancing method by driving torque excitation at a rotational speed, below the first critical speed. Based on the analytical results, a method is next discussed for calculating the modal unbalance from a measured Q value at resonance of the bearing force induced by the torque excitation. N+2 planes balancing are proposed as a universal method after discussion of the optimal number and locations of the balancing planes.

85-412

Microcomputer-Based Instruments Speed Dynamic Balancing to Minimize Steam-Turbine Vibrations

M.J. Wallo
Public Service Electric and Gas Co., Maplewood, NJ

Mech. Engrg., 106 (8), pp 58-61 (Aug 1984) 6 figs

KEY WORDS: Balancing techniques, Diagnostic techniques, Monitoring techniques

A mobile field laboratory housing microcomputer controlled instrumentation for the collection of vibration data, documentation, diagnostics, and field balancing is described. Work on the development of a system to monitor acoustic emission activity on machinery trains as a means for detecting failure modes continues.

85-413

A New View on Balancing Flexible Rotors

M. Balda
Central Res. Inst., Skoda National Corp., Plzen, Czechoslovakia

Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 471-474, 7 refs

KEY WORDS: Balancing techniques, Flexible rotors, Unbalanced mass response

The contribution deals with basic questions concerning balancing flexible rotors, which are modeled by discrete systems of mass points. Some basic properties of systems excited by rotating forces coming from unbalanced masses are presented. A new balancing process is developed, which takes into account an effect of measurement errors.

85-414

Application of Quasi-Modal Concept to Rotational Ratio Response Analysis and New Balancing

O. Matsushita, M. Ida, R. Takahashi
Mech. Engrg. Res. Lab., Hitachi Limited, Ibaraki, Japan

Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 427-437, 27 figs, 1 tables, 7 refs

KEY WORDS: Quasi-modal analysis, Harmonic excitation, Balancing techniques, Rotors

In this study, a rotor vibration analysis for the response due to harmonic excitation, in particular, the multiple frequency of rotational speed, is developed. A computer aided design for unbalance vibration, vibration due to balls or blade passing, is reviewed. This new technique is based upon the concept of quasi-modal transformation, which is more applicable than the modal one.

MONITORING

85-415

Vibration Monitoring Strategy for Large Turbogenerators

D.L. Thomas
Services Dept., Central Electricity Generating Board, South Western Region, Bristol

Vibrations in Rotating Machinery, Proc. of the 3rd Intl. Conf. Institution of Mech. Engineers, Univ. of York, Heslington, Yorkshire, Sept 11-13, 1984, pp 91-99, 1 table

KEY WORDS: Monitoring techniques, Turbogenerators

This paper briefly describes the evolution of off-line vibration monitoring techniques at the Central Electricity Generating Board. A monitoring strategy which includes return-to-service, on-load and run-down measurements is described. The fixed and recurrent costs incurred if this strategy is implemented are than considered, followed by a detailed examination of the financial benefits. The benefits are illustrated by a number of examples of the successful use of monitoring to reduce operating costs. These examples include generator end bell movement, rubbing, thermal bends and sticking windings on generator rotors, and oil whirl caused by misalignment. It is shown that a benefit-to-cost ratio exceeding 10:1 can be achieved, and that this rises to 17:1 if additional benefits arising from crack detection are included. The paper then compares conventional off-line techniques with computer based on-line systems now becoming available, and concludes that a good financial case for on-line systems is likely to exist.

ANALYSIS AND DESIGN

ANALYTICAL METHODS

85-416

A Numerical Method for Free Vibration Analysis of Structures with Small Design Changes

F. Kikuchi, T. Aizawa
Univ. of Tokyo, Tokyo, Japan

Bull. JSME, 27 (229), pp 1479-1486 (July 1984) 5 figs, 8 tables, 12 refs

KEY WORDS: Eigenvalue problems, Perturbation theory, Numerical analysis

Small design changes are usually repeated at design phase of structures, and it appears to be of practical significance to develop effective numerical methods for analysis of free vibration problems of structures with small perturbations. This paper presents a numerical method for perturbation analysis of matrix eigenvalue problems, where the eigenpairs necessary to be considered are assumed to be non-degenerate in unperturbed states. The proposed method is based on an iteration scheme combined with the use of generalized inverses of singular matrices. The scheme is designed to be easily implemented on large-scale finite element programs. To see effectiveness and fundamental properties of the proposed method, some numerical results are given for lateral vibrations of cantilever beams and circular plates.

85-417

Numerical Methods for Nonlinear Elliptic Eigenvalue Problems

T.F. Chan

Yale Univ., New Haven, CT
Rept. No. DOE/ER/10996-T2, 6 pp (Mar 30, 1984)
DE84010408

KEY WORDS: *Eigenvalue problems*, Numerical analysis

This project deals with the problem of solving nonlinear eigenvalue problems, namely, nonlinear systems with parameter dependence, primarily through the use of continuation methods. One of the major issues that we are interested in is in solving large and sparse problems. A primary goal of this project is to develop a well-documented piece of mathematical software that incorporates results from our algorithmic studies (and others) and that can be used to trace solution curves of nonlinear eigenvalue problems.

85-418
Reanalysis of Mechanical Structures (Reanalyse de Structures Mecaniques)
A. Naji
Ph.D. Thesis, Franche-Comte Univ., Besancon, France, 163 pp (1983) N84-25099 (In French)

KEY WORDS: Substructuring methods, Finite element technique

Techniques of the dynamic structural analysis of modified mechanical structures are reexamined. Dynamic systems models are developed through the use of algorithms that employ substructure dynamic methods and the finite element method. A new model is developed and a simple example discussed.

85-419
Suddenly-Loaded Structural Configurations
G.J. Simitses
Georgia Inst. of Tech., Atlanta, GA
ASCE J. Engrg. Mech., 110 (9), pp 1320-1334 (Sept 1984) 7 figs, 58 refs

KEY WORDS: Dynamic stability, Elastic systems

The concept of dynamic stability for suddenly-loaded elastic structural configurations is presented. Moreover, the related criteria and estimates of critical conditions are analyzed. It is shown that dynamic *instability of the escaping motion type* (unbounded or large amplitude motion) is only possible for those configurations which, under static loading, exhibit limit point instability. Some conclusions are presented that address the expected response of real world situations, as opposed to responses predicted by mathematical modeling.

85-420
An Analytical Solution for the Transient Response of Saturated Porous Elastic Solids
B.R. Simon, O.C. Zienkiewicz, D.K. Paul
Univ. of Arizona, Tucson, AZ 85721
Intl. J. Numer. Anal. Methods Geomech., 8 (4), pp 381-398 (July/Aug 1984) 6 figs, 3 tables, 13 refs

KEY WORDS: Transient response, Porous materials

The general forms for the field equations governing the transient response of poroelastic media given by Biot and by Zienkiewicz are compared and relations between the material constants are obtained. A one-dimensional analytical solution is presented for the situation where the solid and fluid materials satisfy Biot's dynamic compatibility relation. The transient response of porous media is illustrated for varying degrees of solid and fluid compressibility when subjected to step, cyclic and short duration spike surface tractions. The results obtained exhibit the overall characteristics of wave propagation in porous media and will provide representative test problems which allow a quantitative evaluation of accuracy of various numerical solution methods.

85-421
An Integral Equation Method for the First-Passage Problem in Random Vibration

P.H. Madsen, S. Krenk
Riso National Lab., Roskilde, Denmark
J. Appl. Mech., Trans. ASME, 51 (3), pp 674-679 (Sept 1984) 7 figs, 18 refs

KEY WORDS: Random vibrations, Integral equations

The first-passage problem for a nonstationary stochastic process is formulated as an integral identity, which produces known bounds and series expansions as special cases. Approximation of the kernel leads to an integral equation for the first-passage probability density function. An accurate, explicit approximation formula for the kernel is derived, and the influence of uni or multi modal frequency content of the process is investigated. Numerical results provide comparisons with simulation results and alternative methods for narrowband processes, and also the case of a multimodal, nonstationary process is dealt with.

85-422

Dynamic Analysis of Porous Medium Problems by the Finite Element Methods

James Shih-Shyn Wu
Ph.D. Thesis, Univ. of Arizona, 494 pp (1984) DA8412684

KEY WORDS: Finite element technique, Equations of motion, Porous materials

General anisotropic constitutive laws and relevant dynamic equations of motion for porous media are described. The accuracy of various discretization algorithms in space and in time was surveyed. Results of these models and algorithms were compared to the exact solutions. Appropriate models and algorithms for further studies of spinal motion segments were then determined.

85-423

Dual Channel FFT Analysis (Part II)

H. Herlufsen
Tech. Rev. (B & K), 2, pp 3-45 (1984) 20 figs, 30 refs

KEY WORDS: Fast Fourier transform, Frequency response function, Time domain method, Impulse response

In the first part of this article the basic dual channel FFT measurement was introduced and frequency response function estimates and excitation techniques were discussed. In the second part of this article the time domain functions, impulse response function, autocorrelation and cross correlation and their physical interpretation is dealt with in some detail. The implementation of the Hilbert transform on these time domain functions, to compute the corresponding complex and analytical signals, is introduced. The advantages of using the magnitude in the presentation of these functions in some practical situations are illustrated. Calculation of sound intensity from a dual channel measurement of the sound pressure signals from two closely spaced microphones is discussed in terms of advantages and disadvantages.

85-424

Integrating Factors and Conservation Laws for Nonconservative Dynamical Systems

D.S. Djukic, T. Sutela
Univ. of Novi Sad, V. Vlahovica 3,21000 Novi Sad, Yugoslavia
Intl. J. Nonlin. Mech., 19 (4), pp 331-339 (1984), 52 refs

KEY WORDS: Stability analysis

A general approach to the construction of conservation laws for classical nonconservative dynamical systems is presented. The conservation laws are constructed by finding corresponding integrating factors for the equations of motion. Necessary conditions for existence of the conservation laws are studied in detail. A connection between an a priori known conservation law and the corresponding integrating factors is established. The theory is applied to two particular problems.

85-425

Improved Method for the Discrete Fast Fourier Transform

S. Sorella, S.K. Ghosh
Instituto di Fisica and Unita' del Gruppo Nazionale di Struttura della Materia del CNR, Universita dell'Aquila, 67100 L'Aquila, Italy
Rev. Scientific Instrum., 55 (8), pp 1348-1352 (Aug 1984), 1 fig, 3 tables, 6 refs

KEY WORDS: Fast fourier transform

A new algorithm is proposed for discrete fast Fourier transform with reduced aliasing known to be inherent in conventional algorithms, unless the function is band limited and the sampling frequency satisfies the Nyquist condition. Like the algorithm recently proposed by Schutte and extended by Makinen in this journal, this is also based on the polynomial expansion of the function to be transformed. Its power is demonstrated with a few non-band-limited functions that can be exactly transformed with chosen limits. In all cases tried, this yields, in general, much improved accuracy in comparison to others at little or no corresponding increase of computation time.

85-426

Forced Vibration of Nonlinear System with Symmetrical Piecewise-Linear Characteristics

T. Watanabe
Yamanashi Univ., Takeda 4-4-37, Kofu, Japan
Bull. JSME,27 (229), pp 1493-1498 (July 1984), 7 figs, 9 refs

KEY WORDS: Periodic response, Single degree of freedom systems, Approximation methods, Exact methods

The steady state response of a single-degree-freedom system with clearance and triangular hysteresis loop characteristics which are described by a symmetrical piecewise-linear model. Analytical methods of exact and approximate solutions are introduced for the system. The resonance curves are obtained for the amplitude versus the frequency ratios with respect to several fixed exciting ratios and system characteristics utilizing a digital computer. Some numerical results obtained from exact solutions are compared with those from approximate solutions, and these theoretical results are confirmed by analog computer solutions. It is concluded that the approximate solutions are more practical than the exact solutions for a system with low ratios of nonlinear parameters.

85-427

A Field Method and Its Application to the Theory of Vibrations

B. Bujanovic
Univ. of Novi Sad 21000 Novi Sad, Yugoslavia
Intl. J. Nonlin. Mech., 19 (49), pp 383-396 (1984), 10 refs

KEY WORDS: Equations of motion, Perturbation theory

Integration of the differential equations of motion of a nonconservative dynamical system is replaced by an equivalent problem of finding a complete integral of a quasi-linear partial differential equation of the first order. These complete integrals are combined with the two time scales perturbation method in the study of nonlinear oscillatory motions.

MODELING TECHNIQUES

85-428

Numerical Formulation for a Higher Order Plane Finite Dynamic Element

K.K. Gupta
NASA Ames Res. Ctr., Dryden Flight Res. Facility, Edwards, CA
Intl. J. Numer. Methods Engrg., 20 (8), pp 1407-1414 (Aug 1984), 4 figs, 1 table, 10 refs

KEY WORDS: Finite element technique, Free vibration, Numerical analysis

The paper describes the development of an eight-node plane rectangular finite dynamic

element. It presents detailed descriptions of the associated numerical formulation involving the higher order dynamic correction terms pertaining to the related stiffness and inertia matrices. Numerical test results of free vibration analyses are presented for the newly developed eight-node element and also the corresponding four-node element. This will make a clear comparison of the relative efficiencies of the corresponding finite element and dynamic element procedures. Such results indicate a superior pattern of solution convergence of the presently developed dynamic element.

NUMERICAL METHODS

85-429
Application of Desk Top Computers in Machine Dynamics. Part 1: Time-Variant Vibration Systems (Einsatz von Tischrechnern in der Maschinendynamik. Teil 1: Zeitvariante Schwingungssysteme)
V. Schnauder, N. Eicher
Berlin, W. Germany
VDI-Z, 126 (13), pp 493-498 (1984), 3 figs, 2 tables, 12 refs (In German)

KEY WORDS: Computer-aided techniques, Numerical analysis, Machinery vibration, Microcomputers

In this contribution special numerical methods of machine dynamics are discussed and their applicabilities with the aid of desk top computers. Through appropriate analytical preparation of the equations of motion numerical integration can be avoided. This allows to perform vibration calculations by means of desk top computers i.e. calculations which were hitherto reserved for large computers.

STATISTICAL METHODS

85-430
Cumulant-Neglect Closure for Non-Linear Oscillators Under Random Parametric and External Excitations
W.F. Wu, Y.K. Lin
Univ. of Illinois at Urbana-Champaign, Urbana, IL 61801
Intl. J. Nonlin. Mech., 19 (4), pp 349-362 (1984), 7 figs, 18 refs

KEY WORDS: Nonlinear systems, Random excitation, Stochastic processes

The statistical moments of a nonlinear system responding to random excitations are governed by an infinite hierarchy of equations. Therefore, suitable closure schemes are needed to compute the more important lower order moments approximately. One easily implemented and versatile scheme is to set the cumulants of response variables higher than given order to zero. This is applied to three nonlinear oscillators with very different dynamic properties, and with Gaussian white noises acting as external and/or parametric excitations. It is found that the accuracy of computed second moments can be improved greatly by extending from the second order closure (Guassian closure) to the fourth order closure. Further refinement is unnecessary for practical purposes. Treatment of nonstationary transient response is also illustrated.

PARAMETER IDENTIFICATION

85-431
Parameter Identification Problems in Structural and Geotechnical Engineering
F.E. Udwadia, J.A. Garba, A. Ghodsi
Univ. of Southern California, Los Angeles, CA 90089
ASCE J. Engrg. Mech., 110 (9), pp 1409-1432 (Sept 1984) 14 figs, 9 refs

KEY WORDS: Parameter identification technique, Structural response

This paper investigates some problems related to the ill-posedness of parameter identification problems which are commonly met with in structural and geotechnical

engineering. Viewing the identification problem within a suitable framework, two basic types of ill-posedness are introduced. The first is inherent to the system while the second is related to the type of data that is acquired at a given location and the basic algorithms used in the identification process. Examples of each type of ill-posedness are analyzed.

85-432

Distributed Parameter System Identification: A Survey

C.S. Kubrusly
Control Theory Ctr., Warwick Univ., Coventry, UK

Rept. No. R-94, 47 pp (Sept 1975) PB84-205061

KEY WORDS: System identification techniques, Continuous parameter method

This report presents a survey of methods for the distributed parameter system identification problem. Fundamental concepts such as system identification and distributed parameter systems are briefly summarized in order to make precise what kind of problem will be considered here. The various identification methods are grouped into three disjoint classes, namely: direct method, reduction to a lumped parameter system, and reduction to an algebraic equation. Under this classification, a general survey of the main approaches to the problem of identification in distributed systems is given.

OPTIMIZATION TECHNIQUES

85-433

Optimization of Structures with Frequency Constraints

V.B. Venkayya, V.A. Tischler
Air Force Wright Aeronautical Labs., Wright-Patterson Air Force Base, OH

"Computer Methods for Nonlinear Solids and Structural Mechanics," Appl. Mech., Bioengrg., Fluids Engrg. Conf., Houston, TX, June 20-22, 1983, ASME-AMD Vol. 54, 1983, S. Atluri and N. Perrone, eds., pp 239-259, 7 figs, 9 tables, 10 refs

KEY WORDS: Optimization, Frequency constraints

The subject of this paper is the optimal design of structures with frequency requirements. Two types of problems were addressed. The first problem is a minimization of structural mass subject to a fundamental frequency constraint, and the second problem is a maximization of the fundamental frequency for a given structural mass. An iterative algorithm and a scaling procedure were developed for the optimal design of structures. The procedure was applied to two problems involving the longitudinal vibration of a rod and the vibration of a truss. The results obtained for the longitudinal vibration of the rod compared very well with the closed form solutions available in the literature.

COMPUTER PROGRAMS

85-434

NASTRAN Analysis Comparison to Shock Tube Tests Used to Simulate Nuclear Overpressures

T.K. Wheless
Aeronautical Systems Div., Wright-Patterson AFB, OH

Rept. No. ASD-TR-84-5006, ASD-ENSS-84-1, 56 pp (May 1984) AD-A142 290

KEY WORDS: NASTRAN (computer programs), Shock tube testing, Nuclear explosion effects

This report presents a study of the effectiveness of the NASTRAN computer code for predicting structural response to nuclear blast overpressures. NASTRAN's effectiveness is determined by comparing results against shock tube tests used to simulate nuclear overpressures. Seven panels of various configurations are compared in this study. Panel deflections are

the criteria used to measure NASTRAN's effectiveness. This study is a result of needed improvements in the survivability/-vulnerability analyses capabilities of weapon systems subjected to nuclear blast.

85-435
Probabilistic One-Dimensional Ground-Shock Code for Layered Nonlinear Hysteretic Materials
B. Rohani, J.D. Cargile
Army Engineer Waterways Experiment Station, Vicksburg, MS
Rept. No. WES/MP/SL-84-6, 42 pp (Apr 1984) AD-A142 016

KEY WORDS: Computer programs, Shock waves, Wave propagation, Layered materials

This report describes the conversion of the WES ONED code into a probabilistic code using the partial derivatives method. This is a deterministic one-dimensional plane wave propagation code which treats the response of layered nonlinear hysteretic media to airslap loadings. The merits of this probabilistic solution technique are demonstrated for an actual field explosive test and the code is evaluated against a closed-form probabilistic solution.

85-436
Construction of Inelastic Response Spectra for Single-Degree-of-Freedom Systems: Computer Program and Applications
S.A. Mahin, J. Lin
California Univ., Richmond, CA
Rept. No. UCB/EERC-83/17, NSF/CEE-83030, 96 pp (June 1983) PB84-208834

KEY WORDS: Computer programs, Single degree of freedom systems, Viscous damping

This report describes a computer program written to analyze the inelastic response of viscously damped single-degree-of-freedom systems to either support excitation or external loadings. Various methods of developing design aids based on computed inelastic response are discussed. The program was written to allow the user to conveniently obtain detailed information regarding the inelastic response of a system and to study systematically the effect of variations in the mechanical and dynamic characteristics of the system.

85-437
Structure Dynamics. Determination of the Coupled Relationships in Solid-Fluid-Gas Dynamics
H. Hofmann, A. Huber, T. Naehring, S. Bonakdarzadeh
SDK Ingenieuruntemehmen fuer Spezielle Statik, Dynamik und Konstruktion, Loerrach, Fed. Rep. Germany
Rept. No. SDK-Ber-3304, 179 pp (June 1980)
DE84750875 (In German)

KEY WORDS: Computer programs, Dynamic structural analysis, Finite element technique

In the present paper the code concept SAN (Structure Analysis) is presented. SAN is designed according to the modular principle using describing and coordinating modules. SAN is based on the discreetizing method. It uses compatible forms of description. The method of finite elements is applied. Solid-fluid-gas structures may be described as well as their interrelations in the linear and nonlinear region, including phase transitions with the associated descriptions of material and state.

85-438
NRL (Naval Research Laboratory) Reverberation Model: A Computer Program for the Prediction and Analysis of Medium-to Long-Range Boundary Reverberation
E.R. Franchi, J.M. Griffin, B.J. King
Naval Res. Lab., Washington, DC
Rept. No. NRL-8721, 47 pp (May 2, 1984) AD-A142 057

KEY WORDS: Computer program, Reverberation, Oceans, Underwater sound, Wave scattering

This document describes a sequence of computer programs developed to predict long-range, low frequency monostatic or bistatic boundary reverberation from either the ocean surface or bottom. Presented are the theoretical foundations of the reverberation model, the numerical implementation of this theory, and a detailed description of actual program execution. A complete description of all inputs and outputs is included. Finally, examples illustrating the use of the sequence of programs are provided.

85-439
Development of the Three-Dimensional SHAPS Code Capabilities for Application to LMFBR Piping Systems
W.R. Zeuch, C.Y. Wang
Argonne National Lab., Argonne, IL
CONF-840614-8, 9 pp (1984)
DE84005427

KEY WORDS: Computer programs, Piping systems, Fluid-structure interaction

The SHAPS code couples three-dimensional pipe elements and elbows with two-dimensional hydrodynamics in order to account for fluid-structure interaction, motion of fluid due to moving pipes, and deformation of the structure. Each pipe element is formulated with eight degrees of freedom per node to consider translation, rotation, and membrane bending and breathing modes of the structure. This is to calculate the stresses arising from internal pressurization as well as the three-dimensional flexural motion of the piping system.

85-440
TWIST: A Transient Two-Dimensional Intra-Subassembly Thermal-Hydraulics Model for LMFBRs
M. Khatib-Rahbar, E.G. Cazzoli
Brookhaven National Lab., Upton, NY
Rept. No. BNL-NUREG-34213, CONF-840614-47, 7 pp (1984)
DE84010883

KEY WORDS: Computer programs, Nuclear reactors, Transient response

It is concluded that due to physical accuracy and numerical efficiency (5 to 10 times faster than real time) of this model, it provides an excellent tool for study of long duration natural circulation transients in LMFBR assemblies.

GENERAL TOPICS

TUTORIALS AND REVIEWS

85-441
Mechanics of Structures (Mechanique des Structures)
Direction des Recherches, Etudes et Techniques, Centre de Documentation de l'Amement, Paris, France
Rept. No. ISBN-2-7170-738-5, 91 pp (1983)
PB84-209352

KEY WORDS: Reviews, Aircraft, Helicopters, Fatigue tests, Impact tests

A review is given of research being undertaken by the French Ministry of Defense in the field of structural mechanics. Topics include: problems in the calculation of structures, structural tests in aeronautics, coupling structures with their environment; damage mechanics; and airframe engineering and research. Structural problems in the design and manufacture of helicopters; structural problems relative to engines; structures of strategic and tactical engines; mechanics of military propulsive charges; and structures of ships are also covered.

85-442
Machine Foundations: Vibration Damage in Industry. Causes -Remedial Measures

D. Weiner
Swedish Council for Bldg. Res., Stockholm, Sweden
Rept. No. ISBN-91-540-4151-1, 21 pp (1984) (PB84-206614)

KEY WORDS: Machine foundations, Structure-foundation interaction

The principal object of this publication is to facilitate collaboration regarding vibrations between engineers from different countries. These engineers are engaged on the procurement, planning and design, construction and commissioning of industrial plants.

CRITERIA, STANDARDS, AND SPECIFICATIONS

85-443

The Application of Harmonic Analysis in Gear Technology (Die harmonische Analyse als anwendungsbezogenes Hilfsmittel in der Getriebetechnik)

VDI Directive 2144 (VDI Richtlinie 2144), Summarized in VDI-ZT 36 (10), pp 41-42 (Oct 10, 1984). Avail: VDI-GKE, Postfach 1139, 4000 Dusseldorf 1, German Fed. Rep. (In German)

KEY WORDS: Gears, Harmonic analysis, Standards

The VDI Directive 2144 replaces a 1964 VDI Directive "The Plane Crank Mechanisms - General Mass-Force Calculations in a Numeric-Computational Manner." In the present directive the fundamentals of harmonic analysis are summarized, several current procedures are enumerated, two computer programs are recommended and listed, and examples from drive technology are given.

BIBLIOGRAPHIES

85-444

Computerized Mathematical Eigenvalue Models. 1970-July, 1984 (Citations from the NTIS Data Base)

NTIS, Springfield, VA
157 pp (July 1984), PB84-871979

KEY WORDS: Bibliographies, Eigenvalue problems, Mathematical models

This bibliography contains citations concerning various computer programs and techniques used to solve mathematical problems too large and/or complex for manual manipulation. Most of the citations are slanted towards the solution of sophisticated matrices as they relate to the problems of structural design, stability, dynamics, and loading. Computerized theoretical formulas and equations applicable to general areas of engineering are also included. This updated bibliography contains 190 citations, 20 of which are new entries to the previous edition.

AUTHOR INDEX

CALENDAR

MARCH

11-14 Design Engineering Conference and Show [ASME] Chicago, IL (ASME)

18-21 30th International Gas Turbine Conference and Exhibit [ASME] Houston, TX (Intl. Gas Turbine Ctr., Gas Turbine Div., ASME, 4250 Perimeter Park South, Suite 208, Atlanta, GA 30341 - (404) 451-1905)

APRIL

1-3 2nd International Symposium on Aeroelasticity and Structural Dynamics [Deutsche Gesellschaft f. Luft- und Raumfahrt e.V.] Technical Univ. of Aachen, Germany (Symp. Organizing Secretariate, Deutsche Gesellschaft f. Luft- und Raumfahrt, Godesberger Allee 70, D-5300 Bonn 2, W. Germany)

8-12 Acoustical Society of America, Spring Meeting [ASA] Austin, TX (ASA)

14-18 International Conference on Wear of Materials [ASME] Vancouver, BC, Canada (ASME)

15-17 Institute of Acoustics Spring Conference [IOA] York Univ., UK (IOA, 25 Chambers St., Edinburgh EH1 1HU, UK)

15-17 Structures, Structural Dynamics and Materials Conference [ASME] Orlando, FL (ASME)

15-19 2nd Symposium on Interaction of Non-Nuclear Munitions with Structures [Tyndall AFB, FL; Eglin AFB, FL; Kirtland AFB, NM] Panama City Beach, FL (Ms. L.C. Clouston, Registrar, P.O. Box 1918, Eglin AFB, FL 32542 - (904) 882-5614)

22-24 American Power Conference [ASME] Chicago, IL (ASME)

22-26 International Symposium on Acoustical Imaging, The Hague, The Netherlands (J. Ridder, P.O. Box 5046, 2600 GA Delft, The Netherlands)

29-3 31st Annual Technical Meeting and Equipment Exposition [IES] Las Vegas, NV (IES)

MAY

6-8 4th International Symposium on Hand-Arm Vibration [Finnish Inst. of Occupational Health] Helsinki, Finland (I. Pyykko, Inst. of Occupational Health, Laajaniityntie 1, 01620, Vantaa 62, Finland)

6-9 American Society of Lubrication Engineers, 40th Annual Meeting [ASLE] Las Vegas, NV (ASLE)

22-24 Machinery Vibration Monitoring and Analysis Meeting [Vibration Institute] New Orleans, LA (Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 W. 55th St., Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254)

JUNE

3-5 NOISE-CON 85 [Inst. Noise Control Engrg./Ohio State Univ.] Columbus, OH (NOISE-CON 85, Dept. of Mech. Engrg., Ohio State Univ., 206 W. 18th Ave., Columbus, OH 43210 - (614) 422-1910)

19-21 American Control Conference [ASME] Boston, MA (ASME)

24-26 2nd National Conference and Workshop on Tailoring Environmental Standards to Control Contract Requirements [IES] Leesburg, VA (IES)

24-26 Mechanics Conference [ASME/ASCE] Albuquerque, NM (ASME/ASCE)

JULY

2-4 **Ultrasonics International '85,** Kings College, London (Z. Novak, Ultrasonics, P.O. Box 63, Westbury House, Bury St., Guildford, Surrey GU2 5BH, England)

11-13 **International Compressor Engineering Conference,** Lafayette, IN (Purdue Univ., W. Lafayette, IN - (317) 494-2132)

AUGUST

4-8 **International Computers in Engineering Conference and Exhibition** [ASME] Boston, MA (ASME)

5-10 **SAE West Coast International Meeting** [SAE] Portland, OR (SAE)

SEPTEMBER

2-7 **International Gas Turbine Symposium and Exposition** [Gas Turbine Div., ASME; Chinese Natl. Aero-Technology Import and Export Corp.; Chinese Soc. of Aeronautics and Astronautics] Beijing, People's Rep. China (Intl. Gas Turbine Ctr., 4250 Perimeter Park South, Suite 108, Atlanta, GA 30341 - (404) 451-1905)

9-11 **19th Midwestern Mechanics Conference** [Ohio State Univ.] Columbus, OH (Dept. of Engrg. Mech., Ohio State Univ., 155 W. Woodruff Ave., Columbus, OH 43210 - (614) 422-2731)

10-13 **Design Automation Conference** [ASME] Cincinnati, OH (ASME)

10-13 **Failure Prevention and Reliability Conference** [ASME] Cincinnati, OH (ASME)

10-13 **Vibrations Conference** [ASME] Cincinnati, OH (ASME)

16-20 **DIAGNOSTICS - 85** [Technical Univ. Poznan / Polish Academy Sciences] Leszno, Poland (Diagnostics -85, Prof. C. Cempel, Tech. Univ. Poznan, Piotrowo 3, P.O. Box 5, 60-695 Poznan, Poland)

18-20 **INTER-NOISE '85** [Intl. Inst. Noise Control Engrg.] Munich, Fed. Rep. Germany (E. Zwicker, Institut f. Elektroakustik, TU München, Arcisstr. 21, 8000 München 2, Fed. Rep. Germany)

OCTOBER

6-8 **Diesel and Gas Engine Power Technical Conference** [ASME] Grove City, PA (ASME)

8-10 **Lubrication Conference** [ASLE/-ASME] Atlanta, GA (ASLE/ASME)

8-11 **Stapp Car Crash Conference** [SAE] Arlington, VA (SAE)

14-17 **Aerospace Congress and Exposition** [SAE] Los Angeles, CA (SAE)

20-24 **Power Generation Conference** [ASME] Milwaukee, WI (ASME)

22-24 **14th Turbomachinery Symposium** [Turbomachinery Labs.] Houston, TX (Dara Childs, Turbomachinery Labs., Dept. of Mech. Engrg., Texas A&M Univ., College Station, TX 77843)

22-24 **56th Shock and Vibration Symposium** [Shock and Vibration Information Ctr., Washington, D.C.] Monterey, CA (Dr. J. Gordan Showalter, Acting Director, SVIC, Naval Res. Lab., Code 5804, Washington, D.C. 20375-5000 - (202) 767-2220)

NOVEMBER

4-8 **Acoustical Society of America, Fall Meeting** [ASA] Nashville, TN (ASA)

11-14 **Truck and Bus Meeting and Exposition** [SAE] South Bend, IN (SAE)

17-22 **American Society of Mechanical Engineers, Winter Annual Meeting** [ASME] Miami Beach, FL (ASME)

DECEMBER

11-13 **Western Design Engineering Show** [ASME] Anaheim, CA (ASME)

CALENDAR ACRONYM DEFINITIONS AND ADDRESSES OF SOCIETY HEADQUARTERS

AHS American Helicopter Society
1325 18 St. N.W.
Washington, D.C. 20036

AIAA American Institute of Aeronautics and Astronautics
1633 Broadway
New York, NY 10019

ASA Acoustical Society of America
335 E. 45th St.
New York, NY 10017

ASCE American Society of Civil Engineers
United Engineering Center
345 E. 47th St.
New York, NY 10017

ASLE American Society of Lubrication Engineers
838 Busse Highway
Park Ridge, IL 60068

ASME American Society of Mechanical Engineers
United Engineering Center
345 E. 47th St.
New York, NY 10017

ASTM American Society for Testing and Materials
1916 Race St.
Philadelphia, PA 19103

ICF International Congress on Fracture
Tohoku University
Sendai, Japan

IEEE Institute of Electrical and Electronics Engineers
United Engineering Center
345 E. 47th St.
New York, NY 10017

IES Institute of Environmental Sciences
940 E. Northwest Highway
Mt. Prospect, IL 60056

IMechE Institution of Mechanical Engineers
1 Birdcage Walk, Westminster
London SW1, UK

IFToMM International Federation for Theory of Machines and Mechanisms
U.S. Council for TMM
c/o Univ. Mass., Dept. ME
Amherst, MA 01002

INCE Institute of Noise Control Engineering
P.O. Box 3206, Arlington Branch
Poughkeepsie, NY 12603

ISA Instrument Society of America
67 Alexander Dr.
Research Triangle Pk., NC 27709

SAE Society of Automotive Engineers
400 Commonwealth Dr.
Warrendale, PA 15096

SEE Society of Environmental Engineers
Owles Hall, Buntingford, Hertz.
SG9 9PL, England

SESA Society for Experimental Mechanics (formerly Society for Experimental Stress Analysis)
14 Fairfield Dr.
Brookfield Center, CT 06805

SNAME Society of Naval Architects and Marine Engineers
74 Trinity Pl.
New York, NY 10006

SPE Society of Petroleum Engineers
6200 N. Central Expressway
Dallas, TX 75206

SVIC Shock and Vibration Information Center
Naval Research Laboratory
Code 5804
Washington, D.C. 20375-5000

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PUBLICATION POLICY

Unsolicited articles are accepted for publication in the Shock and Vibration Digest. Feature articles should be tutorials and/or reviews of areas of interest to shock and vibration engineers. Literature review articles should provide a subjective critique/summary of papers, patents, proceedings, and reports of a pertinent topic in the shock and vibration field. A literature review should stress important recent technology. Only pertinent literature should be cited. Illustrations are encouraged. Detailed mathematical derivations are discouraged; rather, simple formulas representing results should be used. When complex formulas cannot be avoided, a functional form should be used so that readers will understand the interaction between parameters and variables.

Manuscripts must be typed (double-spaced) and figures attached. It is strongly recommended that line figures be rendered in ink or heavy pencil and neatly labeled. Photographs must be unscreened glossy black and white prints. The format for references shown in Digest articles is to be followed.

Manuscripts must begin with a brief abstract, or summary. Only material referred to in the text should be included in the list of References at the end of the article. References should be cited in text by consecutive numbers in brackets, as in the following example:

> Unfortunately, such information is often unreliable, particularly statistical data pertinent to a reliability assessment, as has been previously noted [1].

> Critical and certain related excitations were first applied to the problem of assessing system reliability almost a decade ago [2]. Since then, the variations that have been developed and the practical applications that have been explored [3-7] indicate . . .

The format and style for the list of References at the end of the article are as follows:

— each citation number as it appears in text (not in alphabetical order)
— last name of author/editor followed by initials or first name
— titles of articles within quotations, titles of books underlined
— abbreviated title of journal in which article was published (see Periodicals Scanned list in January, June, and December issues)
— volume, issue number, and pages for journals; publisher for books
— year of publication in parentheses

A sample reference list is given below.

1. Platzer, M.F., "Transonic Blade Flutter -- A Survey," Shock Vib. Dig., 7 (7), pp 97-106 (July 1975).
2. Bisplinghoff, R.L., Ashley, H., and Halfman, R.L., Aeroelasticity, Addison-Wesley (1955).
3. Jones, W.P., (Ed.), "Manual on Aeroelasticity," Part II, Aerodynamic Aspects, Advisory Group Aeronaut. Res. Dev. (1962).

Articles for the Digest will be reviewed for technical content and edited for style and format. Before an article is submitted, the topic area should be cleared with the editors of the Digest. Literature review topics are assigned on a first come basis. Topics should be narrow and well-defined. Articles should be 3000 to 4000 words in length. For additional information on topics and editorial policies, please contact:

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